Unit Preparation Booklet

P3.1 Acceleration

Teacher name:

Science Mastery

Ark Curriculum+

Contents

Steps to Success

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Unit preparation checklist

Resources can and should be tailored to meet your pupils' needs. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

Here is a suggested checklist:

Locate:

- ☐ **Find** the unit resources using MyMastery or SharePoint

Engage:

- ☐ Work through the preparation booklet. Complete the pre-unit quiz and mastery quiz yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit)
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

Adapt:

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available

Scope and Sequence

Scope

In this unit pupils will learn how the effect of forces on the motion of objects, looking at Newton's First Law and the effects of balanced and unbalanced forces. They will also look at Newton's Third Law and describe forces in terms of action-reaction pairs. Pupils will learn about the differences between scalar and vector quantities and examples of each, particularly comparing speed and velocity and distance and displacement. They will also learn how to calculate resultant vectors from vectors acting at right angles and how to resolve single diagonal vectors into their horizontal and vertical components. Pupils will also learn about acceleration as the rate of change of velocity and how to calculate it using the change of velocity over time. They will also investigate acceleration themselves including measuring initial and final velocity. They will also learn how to describe motion using velocity-time graphs and interpret these qualitatively and quantitatively. They will also learn how to describe the forces acting on an object based on its motion.

Sequence

Prior to this unit pupils will have an understanding of contact and non-contact forces and how to calculate resultant force. They have also covered the difference between balanced and unbalanced forces and should be able to explain the effects of these in terms of objects changing speed, direction or shape. They have also covered the idea of speed and how to calculate speed using distance and time, as well as how to draw and interpret distance-time graphs. This unit begins with a review of prior knowledge, bringing together understanding of forces and motion. Pupils will then be introduced to the idea of scalars and vectors, which will later help them understand the definition of acceleration as the rate of change of velocity. They will be introduced to calculating resultant vectors using construction of scale diagrams. These are introduced very simply in this context, as not all pupils may have covered Pythagoras' theorem and trigonometric ratios in mathematics by this point. They will then cover Newton's First and Third Law, which they have encountered already in P1.1 but not in such depth. Newton's Second Law will be covered in P4.1, where it will be taught alongside stopping distances and other effects of forces such as deformation. Pupils will then go on to cover acceleration as the rate of change of velocity, building on their understanding of velocity as a vector quantity, as well as how to calculate this. They will carry out the Newton's Second Law practical to develop their skills on how to calculate initial and final velocity, which they will come back to in P4.1, when looking at the effect of force and mass on acceleration. They will then learn how to draw and interpret velocity-time graphs and how to compare these with distance-time graphs and the meanings of the different features of each. Knowledge from this unit will be developed further through looking at more complicated effects of forces and the relationship between force and work done. They will also go on to use their knowledge of velocity to calculate momentum and describe conservation of momentum. They will also develop their understanding of the effects of forces on motion in a real-life context with stopping distances and the factors that affect stopping distances.

Pupils will go on to develop their skills of accurately measuring time and acceleration through further practice of the Newton's Second Law practical. They will also use their application of calculations from this unit to carry out more complex calculations for acceleration and eventually vertical and projectile motion.

A full set of knowledge objectives for this unit can be found as **Appendix 5.**

1	**2**	**3**	**4**
Prior knowledge review.	Scalars and vectors.	Resultant vectors.	Resolving vectors.
5	**6**	**7**	**8**
Newtons third law.	Newtons first law.	Acceleration.	Acceleration investigation.
9	**10**	**11**	**12**
Maths in science 18- Linear graphs	Velocity time graphs.	Velocity time graphs 2.	Acceleration problems.
13			
Review and reteach.			

TASKS:

New teachers: Organise the lesson titles into those you feel most to least confident about *Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year?

Pre-unit quiz

P3.1 Pre-Unit Quiz

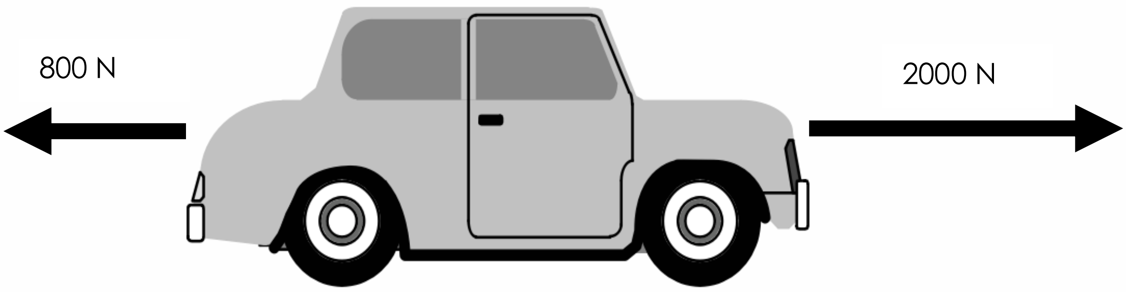
1. Which is the best definition for resultant force? [1]
   Tick (✓) **one** box.

   (a) Equal forces acting in opposite directions ☐

   (b) The overall effect of all the forces acting on an object ☐

   (c) The biggest force acting on an object ☐

The diagram below shows some of the forces acting on a car. Use this diagram to answer Questions 2 to 4.



2. What is the size of the resultant force on this car? [1]
   Tick (✓) **one** box.

   (a) 1200 N left ☐

   (b) 1200 N right ☐

   (c) 2800 N ☐

3. Which option **best** describes the motion of the car? [1]
   Tick (✓) **one** box.

   (a) The car would be stationary ☐

   (b) The car would be moving at a constant speed towards the right ☐

   (c) The car would be accelerating towards the right ☐

4. The backward force increases until it is also 2000 N. Which option **best** describes the new motion of the car? [1]

   Tick (✓) **one** box.

   (a) The car would be moving at a constant speed towards the right ☐

   (b) The car would slow down ☐

   (c) The car would have stopped ☐

5. Which option correctly shows how you would calculate the speed of a car that travelled 1 km in 1 minute? [1]

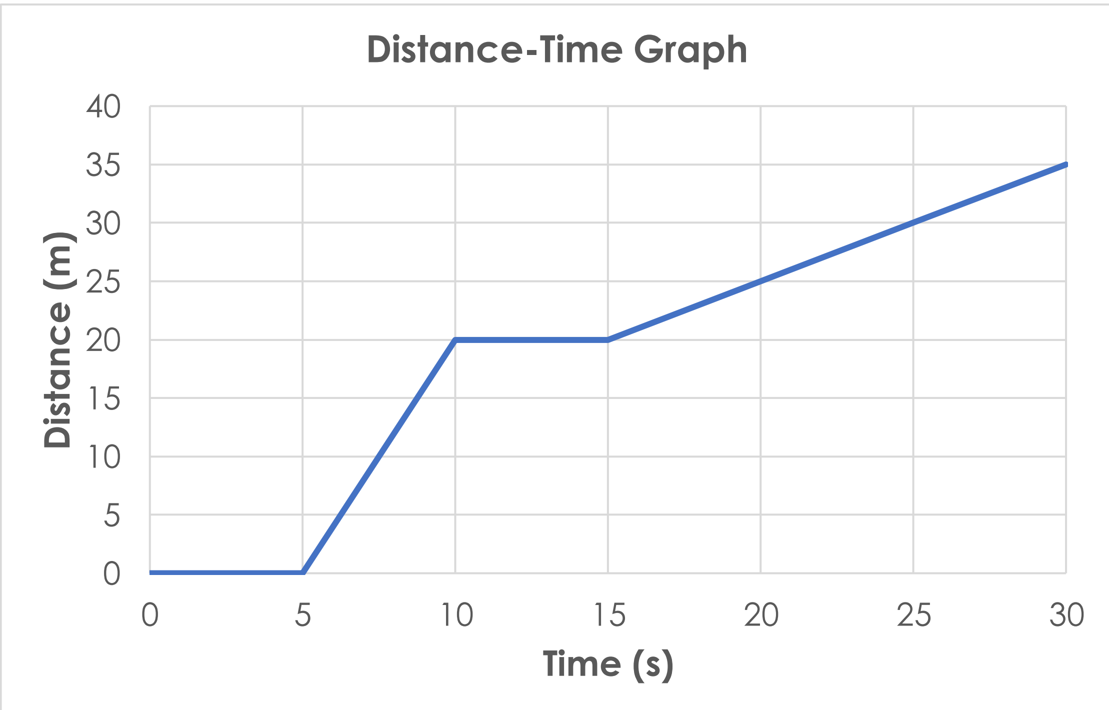
   Tick (✓) **one** box.

   (a) Speed = $\frac{1\text{ km}}{1\text{ minute}}$ ☐

   (b) Speed = $\frac{1000\text{ m}}{60\text{ seconds}}$ ☐

   (c) Speed = 1000 m x 60 seconds ☐

Use the following distance-time graph to answer Questions 6 to 9.



6. When is the object not moving? [1]

Tick (✓) **one** box.

(a) Between 0 and 5 seconds ☐

(b) Between 5 and 10 seconds ☐

(c) Between 15 and 30 seconds ☐

7. When is the object moving fastest? [1]

Tick (✓) **one** box.

(a) Between 5 and 10 seconds ☐

(b) Between 10 and 15 seconds ☐

(c) Between 15 and 30 seconds ☐

8. What is the total distance travelled by this object? [1]

Tick (✓) **one** box.

(a) 40 m ☐

(b) 35 m ☐

(c) 130 m ☐

9. Which is the correct SI unit for speed? [1]

Tick (✓) **one** box.

(a) m/s ☐

(b) mph ☐

(c) km/h ☐

10. A runner runs 1500 m in 500 seconds before resting for 50 seconds. Then she runs another 500 m in 250 seconds. What is her average speed for the whole run? [1]

Tick (✓) **one** box.

(a) 3 m/s ☐

(b) 2.5 m/s ☐

(c) 2.67 m/s ☐

Total = ___ /10

Pre-unit quiz reflections

To be completed once you have reviewed your pupils' response to the pre-unit quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout the unit?

<u>Other notes</u>

Mastery Quiz

TASK: Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

Section A

1. Choose which of the following is a vector quantity. [1]

   Tick (✓) **one** box.

   A. Speed ☐

   B. Weight ☐

   C. Mass ☐

2. Choose the best definition of **acceleration**. [1]

   Tick (✓) **one** box.

   A. Change in velocity ☐

   B. Increase in speed ☐

   C. Change in direction ☐

3. Newton's Third Law states that … [1]

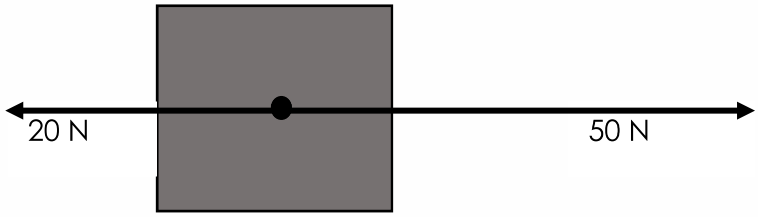
   Tick (✓) **one** box.

   A. an object has the same motion unless an unbalanced force acts on it. ☐

   B. every action has an equal and opposite reaction. ☐

   C. stationary objects have no forces acting on them. ☐

4. Use the diagram below to answer questions 4(a) and 4(b).



(a) If object in the diagram was initially **stationary**, choose the option that best describes the motion as a result of these forces. [1]

Tick (✓) **one** box.

A. The object will move at a constant speed towards the right ☐

B. The object will accelerate towards the right ☐

C. The object will remain stationary ☐

(b) If object in the diagram was initially **moving at a constant speed towards the left**, choose the option that best describes the motion as a result of these forces. [1]

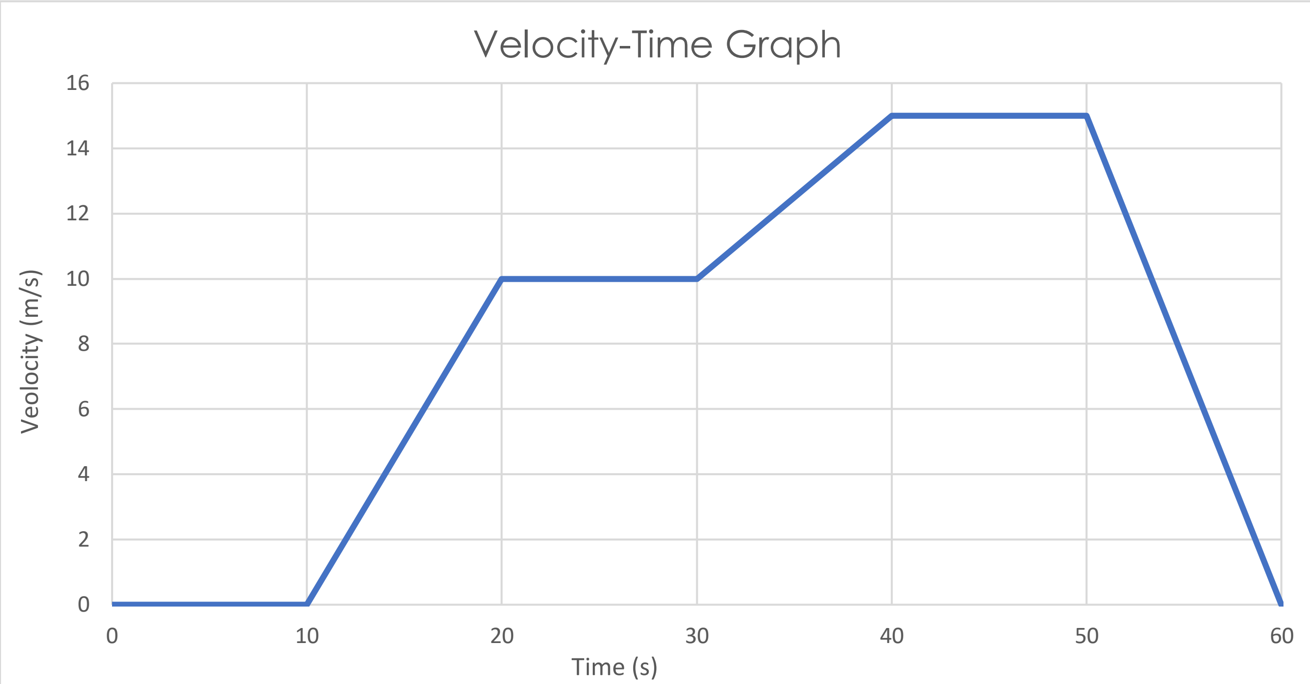
Tick (✓) **one** box.

A. The object will continue at the same speed in the same direction ☐

B. The object will slow down towards the left ☐

C. The object will move towards the right ☐

5. Use the velocity time graph below to answer questions 5(a) to 5(d).



(a) Choose the best description of the motion between 20 and 30 seconds. [1]

Tick (✓) **one** box.

A. The object is travelling slower than between 10 and 20 seconds ☐

B. The object is travelling at a constant speed ☐

C. The object is stationary ☐

(b) Choose the best description of the motion between 50 and 60 seconds. [1]

Tick (✓) **one** box.

A. The object is slowing down to a stop ☐

B. The object is returning to its original position ☐

C. The object is travelling faster than between 10 and 20 seconds ☐

(c) Choose what distance was covered by this object in the first 30 seconds. [1]

Tick (✓) **one** box.

A. 300 m

B. 150 m

C. 500 m

(d) Choose the acceleration between 30 and 40 seconds. [1]

Tick (✓) **one** box.

A. 0.5 m/s^2

B. 0.5 m/s

C. 2 m/s^2

D. 2 m/s

6. The equation $y = mx + c$ represents a linear relationship on a graph.

Choose what 'm' represents in this equation. [1]

Tick (✓) **one** box.

A. The gradient of the line

B. Where the line intercepts the x axis

C. Where the line intercepts the y axis

7. A student investigated the time taken for two different balls to travel

down a 5 m ramp.

A clock was used to measure the time.

The ramp was placed on a block so it was held at the same position.

The results are shown below and there is an anomaly circled.

	Time (seconds)		
Type of ball	**Reading 1**	**Reading 2**	**Reading 3**
Ping-pong ball	4	4	1
Tennis ball	2	2	2

Choose the most likely cause of this anomaly. [1]

Tick (✓) **one** box.

A. A clock doesn't allow measurement of time to 2 decimal places ☐

B. The student forgot to look at the clock so a shorter time was measured ☐

C. The ping-pong ball must have travelled faster on the third reading ☐

8. Choose which measurements are needed to calculate the acceleration of an object. [1]

Tick (✓) **one** box.

A. Final velocity of the object ☐

B. Initial velocity and final velocity of the object ☐

C. Initial velocity and final velocity of the object and the time taken for velocity to change ☐

9. Choose the correct way to calculate the gradient of a line. [1]

Tick (✓) **one** box.

A. Gradient = $\frac{Change\ in\ x}{Change\ in\ y}$ ☐

B. Gradient = $\frac{Change\ in\ y}{Change\ in\ x}$ ☐

C. Gradient = $\frac{Total\ x}{Total\ y}$ ☐

D. Gradient = $\frac{Total\ y}{Total\ x}$ ☐

10. Choose which pair of forces would create the largest resultant force. [1]

Tick (✓) **one** box.

A. Two forces acting at 90º to each other ☐

B. Two forces acting at 180º to each other ☐

C. Two forces acting at 0º to each other ☐

11. Choose the correct method for calculating the acceleration of a car that accelerates from being stationary to 50 m/s in 5 seconds. [1]

Tick (✓) **one** box.

A. $\frac{50-5}{5}$ ☐

B. $\frac{5-0}{50}$ ☐

C. $\frac{0-50}{5}$ ☐

D. $\frac{50-0}{5}$ ☐

$\frac{\quad}{15}$

Section B

1. List three examples of **scalar quantities**.

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2. Describe what is meant by the term **displacement**.

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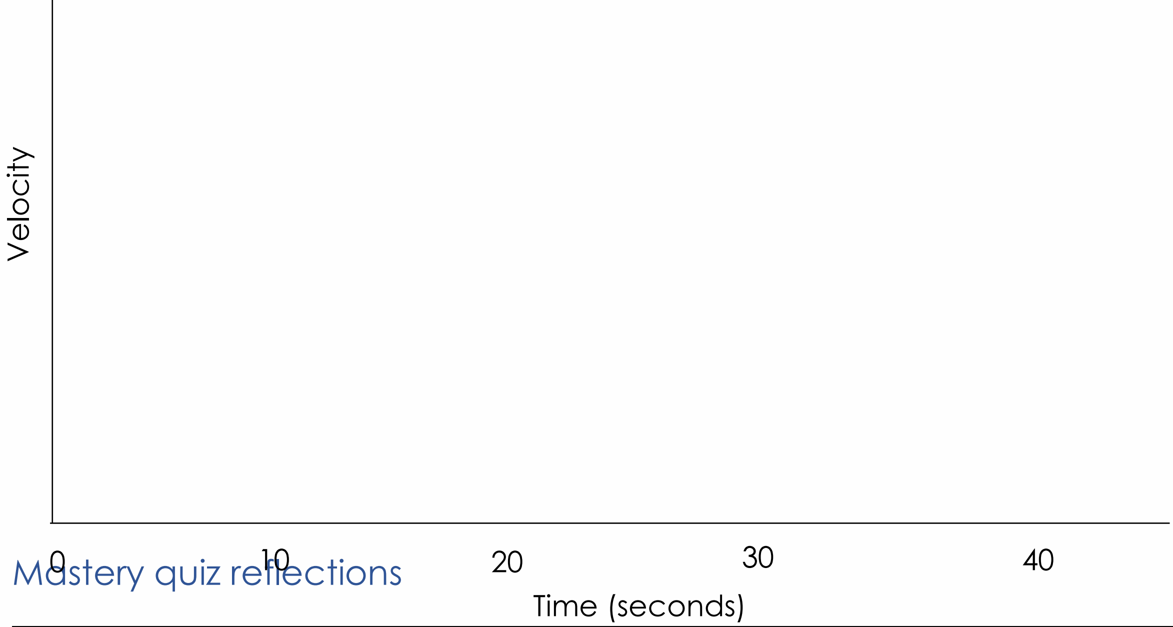
3. An object is moving in a circle at a constant speed.
   Explain why it is correct to say that this object is accelerating.

---

4. Sketch a velocity-time graph on the axes below using this information.
   (Scales are approximate in this diagram)

- A car travelled at a constant acceleration for 10 seconds
- Then the car remained at a constant speed for 10 seconds
- Then the car travelled at a constant deceleration for 20 seconds



Mastery quiz reflections

Which aspects of this unit are likely to be the most challenging to teach?

What are your pupils likely to find most challenging and why?	
Challenging.....	Because....
E.g. The number of new keywords	*They are abstract words that aren't used in other areas of science*
How can you pre-empt some of the key misconceptions the mastery quiz aims to identify?	
Misconception	**How to avoid**

Exam-style questions

TASK: Using exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

How is knowledge from this unit typically assessed? What are the most common questions?
Which question types are the most challenging?
What general trends can you spot in the typical errors pupils make (from examiner reports/notes)?
How could you help prepare your students for answering these types of questions?

Common mistakes, errors, and misconceptions

How would you tackle the following common mistakes, errors, and misconceptions by pupils?

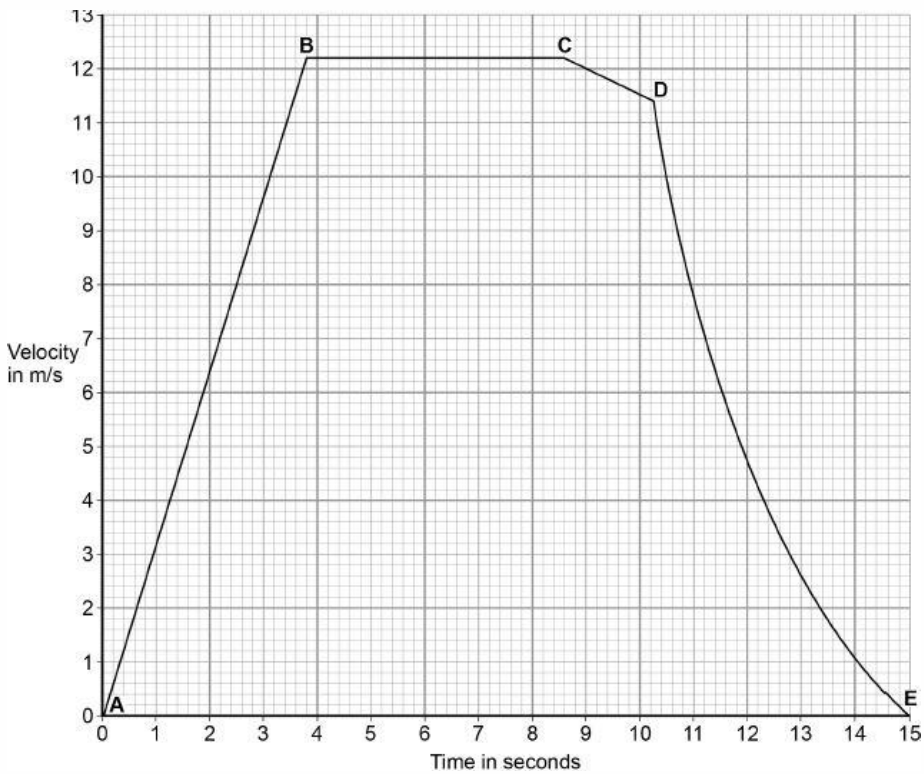
TASK: Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

Mistake	**Reason why it's a mistake**	**Possible approaches to pre-empt and respond?**
If an object is stationary, there are no forces acting on it.	When an object is stationary there are still forces acting on the object, but these forces are balanced. For example, a book resting on a table will still have weight and normal reaction force acting on it.	
Mass is the same as weight. *The object has a weight of 56kg.*	Mass is the amount of matter that makes up a substance and so is a scalar quantity. Weight is the effect of gravity on mass towards the earth and so is a vector quantity.	
When forces are equal and opposite, the forces cancel out.	If forces cancelled out, it would be hard to explain how any objects moved at all. The forces that are equal and opposite may not be acting on the same object. For example, a skate boarder might move forward but the board might move backwards even though they have exerted equal and opposite forces on each other there is still motion.	
When there is a downward slope on a velocity time graph the object has changed direction and is moving the other way.	In a velocity time graph, any point above the X axis, the object is moving in the same direction. When the line goes below the X axis, the object has changed direction.	
Eventually the acceleration will stop and cause the object to stop.	The object will stop because of negative acceleration and another force such as friction.	
General understanding of how fast objects move such as average pace of walking, running, cycling etc.	Typical values may be taken as: walking~1.5 m/s running~3 m/s cycling~6 m/s.	
Gradients describe	Gradients describe the slope of	

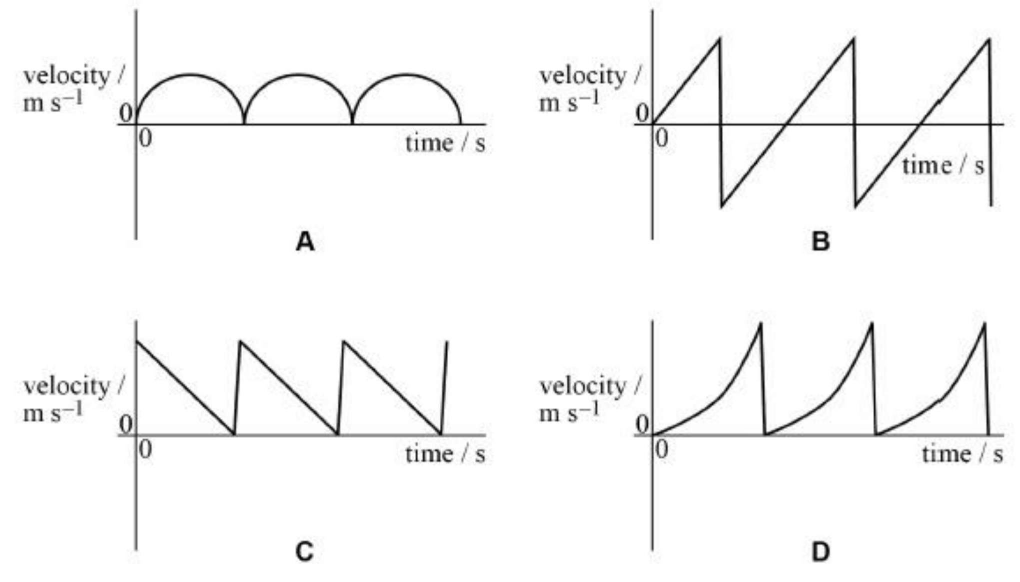
lines on a graph.	the graph either positive or negative gradients can exist on graphs.	
Objects in orbit are not accelerating.	An object moving in a circle is accelerating because it is constantly changing direction which means its velocity is changing (accelerates towards the centre of the Earth).	
You can calculate the acceleration from a velocity-time graph by reading a velocity from the Y axis and time from the x axis.	Students need to use the gradient of the line. Therefore, should use **change** in y/ **change** in x.	

Planning for the misconceptions

Misconception: When there is negative velocity, the object has changed direction and is moving the other way.
Velcoity is a vector quantity that is used to describe motion with a direction in 1 dimention. Students can use velocity time graphs to describe motion of objects. A velocity time-graph only indicates direction if lines move across the X axis. In the example below. The line does not cross the x axis and so the object is moving in the same direction.

When looking at this graph students should be able to descirbe the motion at each stage. **A-B:** The objects velocity is increasing. It has a constant acceleration. **B-C**: The object is at a constant velocity and no acceleration. **C-D**: The object has a decreasing velocity and a constant negative acceleration. **D-E:** The object has decreasing velocity and because the line is curved there is not constant negative acceleration. Where the line is steepest the negative acceleration is greatest.
Supporting pupil understanding
Doing a model of 'draw my motion' in the classroom can help with understanding this. Students can use their mini whiteboards and draw axis with time on the x axis and velocity on the Y axis. The teacher can walk across the classroom varying speeds and emphasise when accelerating and decelerating. Students can show this in a sketch graph. The teacher can show that the teacher is not moving backwards but is also not accelerating.
Taking it further

At A-level students are asked to apply undertsanding of these graphs to a bouncing ball:

Which graph best represents the velocity–time graph for a ball that is dropped from rest and bounces repeatedly?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

Here the answer is not A because this shows the distance time.
The answer is not C because this shows the acceleration.

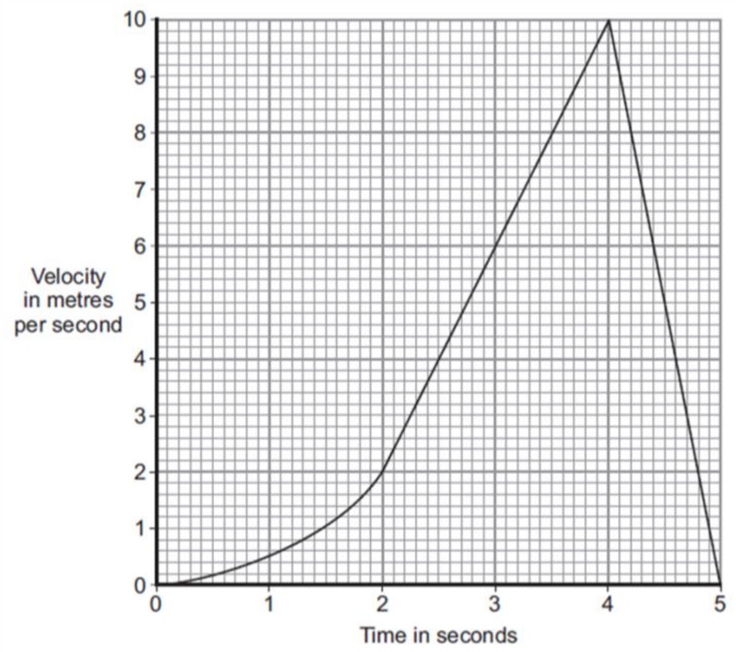
B shows velocity becuase it shows the ball initially accelerating as it is dropped. As the ball bounces the direction of the velocity is instantaneously reversed then the ball decelerates as it is moving upwards but being pulled by gravity. Finally as the ball begins to fall again it is accelerating again. This process repeats as the ball continues to bounce.

Misconception: You can calculate the acceleration from a velocity-time graph by reading a velocity from the Y axis and time from the x axis.

Students learn the equation: **Acceleration= change in velocity/time**.
This is one of the equations that is provided on the equation sheet. The students could be asked to apply this equation to a velocity time graph. Students often don't realise that they need to find the gradient of the line by finding the difference rather than taking raw data from the graph.

Take this exam question; students will have been exposed to these types of velocity time graphs in lessons before. They should be able to describe the motion of this object and explain what is happening at 4 seconds. For example:

The object has increasing velocity from 0 seconds to 4 seconds, with acceleration being greatest between 2 seconds and 4 seconds. At 4 seconds the objects velocity decreases rapidly until 5 seconds when there is no more velocity.



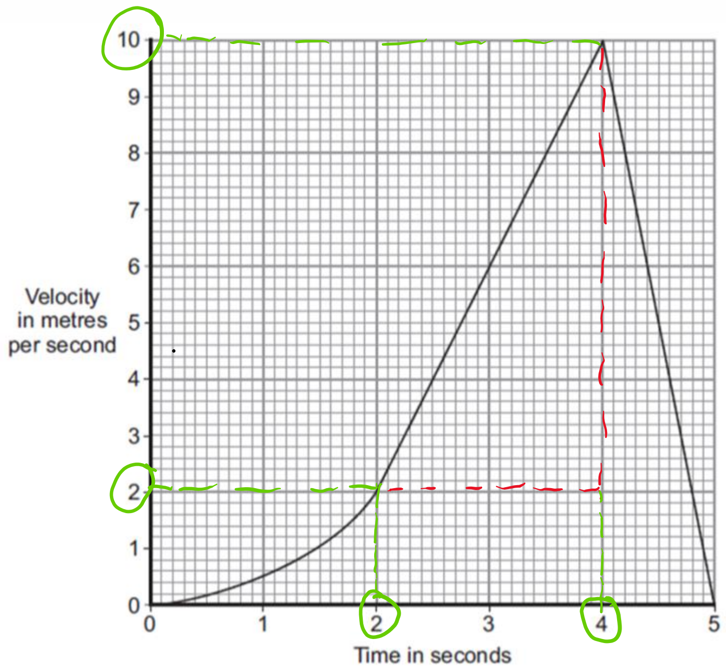
However, if asked to calculate acceleration students often find it hard to decide where to take data from the graph.
This is the question:

Use the graph to calculate the acceleration of the car just before the collision with the barrier.

*Show clearly how you work out your answer, **including how you use the graph**, and give the unit.*

The important part of the question is highlighted in bold. The students should draw on the graph for this question. The examiners' report suggests that most students were unable to calculate the change in velocity and instead chose 2m/s as the velocity.

Students should draw a triangle on the graph to calculate the change in velocity and the time. They should make this very clear, see model below.



Gradient = $\frac{\text{change in } y}{\text{change in } x}$

$a = \frac{\Delta \text{velocity}}{\Delta \text{time}}$

$a = \frac{10-2}{4-2}$

$a = \frac{8}{2}$

$a = 4\ m/s^2$

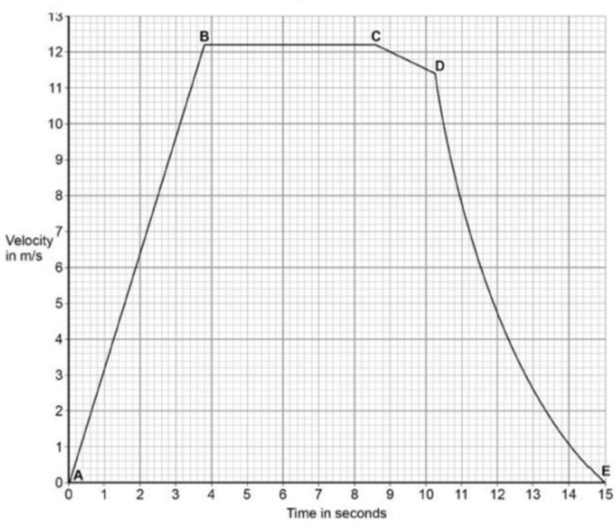
Supporting pupil understanding

This process could be modeled using a visualiser. It is really important that students get into good habits when asked to read data from graphs.

1. Use a ruler to draw a dashed line from the axis.
2. Circle the numbers you will use in your calculations.
3. Show every step of the calculation that you will do.
4. Remember to include units in your answer.

Taking it further

Figure 1



Higher tier can be asked to calculate the gradient of a line when the line is not straight by drawing a tangent. Students will learn this skill in maths too. Here students will use a ruler to create a tangent on a curve.
For example:

The acceleration is **not** constant from **D** to **E**.

Determine the acceleration at a time of 12.0 s.

Use **Figure 1 (5 marks).**

Give the unit.

The examiner's report for this question says that only 4% of students had the appropriate maths skills to draw a tangent on the curved part of the line (at 12 seconds). With most of the students taking coordinates from the graph at certain points but failing to calculate the gradient.

Misconception: Speed and velocity are the same.
Speed and velocity are often used in the same way and they have the same units (m/s) which can cause some confusion with the two words. They are also used in the same way in everyday language. The speed of an object tells you have fast something is going and there for is a vector quantity. However, the velocity of an object tells you have fast something is moving in a given direction. This means velocity is a scalar quantity. A person might be walking across a park forwards and backwards at a constant speed of 2m/s however, speed gives us no indication of the direction the person is moving in. However, if we use velocity, then we can say that the person is moving +2m/s to the right or -2m/s to the left. This helps to create a more precise account of the persons motion across the park.
Questions that apply this understanding.
An example of how you could apply this is thinking about a car driving around a corner at a constant speed. The car's speed is unchanged, but the velocity has changed. ***Astronauts have landed on the Moon on six separate occasions.*** ***(a) The Moon is in a circular orbit around the Earth. The speed of the Moon is constant.*** ***Explain why the Moon is accelerating (3).*** In this question students should be able to explain that acceleration is the rate of change of velocity. The examiners report says that three quarters of students scored no marks in this question. 11% made no attempt to answer the question at all. Few students were able to make the link in the question to the vector nature of velocity and acceleration. With explain questions- it is a good idea to get students into the habit of using 'This means that…' or 'therefore' in their answer. **Model answer:** • The moon is a natural satellite that is in circular motion orbiting around the Earth. • The direction of the moon is constantly changing. • **This means that** velocity is constantly changing. • Acceleration is the rate of change of velocity **therefore** the moon is accelerating.

Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that TBAT = to be able to

Critical: it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
Core: it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
Stretch: pupils should have the opportunity to be work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
Key skill: pupils should have the opportunity to develop this key skill as part of this unit.

Intended outcome for separate sciences pupils are denoted in blue and italised.

Lesson 1: Prior knowledge review

Intended outcome	Example questions
*This lesson is a review of content from previously studied units relating to this big idea	
TBAT Define speed and state the equation that links speed, distance and time.	Define speed State the equation that links speed, distance and time State the SI units for speed, distance and time Use the equation to calculate speed, distance or time Calculate the average speed of an object during a journey
TBAT Identify forces and draw free-body force diagrams.	Identify the forces acting on a book sitting on a table Identify the forces acting on a skydiver Draw a free body force diagram to show the forces acting on a book sitting on a table Draw a free body force diagram to show the forces acting on a skydiver
TBAT Describe the journey of an object on a distance time graph.	Identify the quantities that go on the x and y axis of a distance-time graph Explain what a horizontal line means on a distance-time graph Compare the speed of an object at different points on a distance-time graph
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 2: Scalars and vectors

Intended outcome	Example questions
*This lesson is a review of content from previously studied units relating to this big idea	

TBAT Give examples of vector and scalar quantities.	Give examples of vector quantities. Give examples of scalar quantities. Explain why speed is a scalar quantity and velocity is a vector quantity.
TBAT Define speed and velocity.	Define speed. Define velocity. State how speed and velocity are different. Compare speed and velocity.
TBAT Define displacement.	Define displacement. Compare displacement and distance.
TKT Vector quantities can be represented by an arrow that is proportional to its magnitude and shows its direction.	State whether this diagram shows a vector or a scalar quantity.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 3: Resultant vectors

Intended outcome	Example questions
TKT A resultant vector is the combination of two or more single vectors such as resultant force.	Define resultant vectors.
TKT Vectors acting in the same direction are added together, opposite directions are subtracted.	Calculate the resultant force from these diagrams. (students should be shown simple force diagrams with 2 arrows, some acting in the same direction, some acting in opposite directions).
TKT The resultant of two vectors at right angles to eachother can be determined by a calculation or a scale drawing (**Higher tier only).**	Students could be asked to draw scale diagrams when they are given force sizes. For example, 2N and 5N at right angles. They can be asked to calculate the resultant force by drawing a line between these and using the scale to calculate magnitude.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 4: Resolving Vectors

Intended outcome	Example questions
TKT A single force can be resolved into two components acting at right angles to each other.	Calculate the resultant force acting on this object when there are 2 other forces at right angles to each other.
TKT The vertical and horizontal component forces together have the same effect as the single force	
TBAT Determine a resultant vector using a scale diagram.	Draw a scale diagram to represent the forces acting on this object. Calculate the resultant force from the scale diagram.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 5: Newton's Third Law

Intended outcome	Example questions
TKT Newton's Third Law states that every action has an equal and opposite reaction	Describe Newtons Third law of motion. Explain why this object does not move using Newtons Third Law of motion.
TKT This means that if object A exerts a force on object B, object B exerts an equal and opposite force on object A.	Describe the force acting on object A if object B exerts a force of 10N.
TBAT Draw free-body force diagrams.	Draw a free body diagram to represent the forces acting on this object.
TKT The names and definitions of common forces.	Name the force acting on the object which pulls it to the ground. State the force acting on the object as it slows down. State the forces acting on the skateboarder.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 6: Newton's First Law

Intended outcome	Example questions
TBAT define inertia	Describe Newtons First law of motion Define inertia
TBAT state the resultant force acting on an object at equilibrium	An object is stationary. What is the resultant force acting on it? An object is moving at a constant speed. What is the resultant force acting on it?
TBAT Describe the possible effects of unbalanced forces	Identify if forces are balanced or unbalanced Define resultant force Explain what is meant by a non-zero resultant force Explain what it means if the resultant force is 0 Describe the three different effects an unbalanced (non-zero) resultant force can have
TBAT determine the motion of an object from the forces acting upon it	A stationary object has balanced forces acting on it, describe its motion A stationary object has an unbalanced force acting on it, describe its motion An object at constant speed has balanced forces acting on it, describe its motion An object at constant speed has an unbalanced force acting on it, describe its motion
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 7: Acceleration

Intended outcome	Example questions
TKT Acceleration is the rate of change of velocity.	Define velocity. Define acceleration.
TKT Acceleration is a measure of how quickly an object speeds up, slows down, or changes direction.	
TKT An object moving in a circle is constantly changing direction, therefore it is accelerating.	Explain why the moon orbiting the Earth is accelerating.
TKT A negative acceleration, or slowing down, can be called deceleration.	Define deceleration.
TKT The SI units of acceleration are (m/s2).	State the units for acceleration.
TKT Near the Earth's surface any object falling freely under gravity has an acceleration of about 9.8 m/s2.	State the acceleration of objects falling freely under gravity.
TKT Air resistance/drag increases with speed.	Describe how the trolly eventually stops if someone stops pushing it.
TBAT The acceleration of an object can be calculated using the equation: Acceleration (m/s^2)= (Change in velocity (m/s))/(Time (s)).	Calculate the acceleration of this object if it started at a velocity of 2m/s and finished at a velocity of 10m/s. State the units of acceleration.
TKT The change in velocity can be calculated using the final velocity minus the initial velocity.	Describe how you calculate the change in velocity.
TBAT Relate changes in distance covered per unit time to acceleration of an object.	Describe the motion of the object in terms of acceleration.
TBAT Describe and explain the forces acting on an object that is accelerating	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 8: Acceleration Investigation

Intended outcome	Example questions *Most questions on this topic are in the context of interpreting Punnett squares
TBAT Calculate acceleration using the equation and using initial and final velocity.	Calculate acceleration using the equation provided on the equation sheet.
TBAT Measure the initial and final velocity.	
TBAT Use the equation speed= distance/ time.	Calculate speed of the toy car that has travelled along the 2m ramp.
TBAT Measure time accurately.	
TBAT Measure motion, including determination of speed and rate of change of speed (acceleration/deceleration)	
TKT Any anomalous values should be examined to try to identify the cause and, if a product of a poor measurement, ignored.	Define an anomaly. Calculate the mean from this data set. Suggest an error this student has made with their results calculation.
TKT The difference between independent, dependent and control variable.	State the independent variable in this investigation. State the dependent variable in this investigation. State the control variable in this investigation.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 9: Maths in science 18 - Linear graphs

Intended outcome	Example questions
TKT Understand that y=mx + c represents a linear relationship.	What does y=mx +c represent in a graph?
TBAT Determine the slope and intercept of a linear graph.	Determine the slope and intercept of this linear graph.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 10: Velocity-time graphs

Intended outcome	Example questions
TKT Velocity-time graphs can be used to describe motion.	Describe the motion of the object using the graph. Describe the trend in the graph.
TKT A horizontal like indicates the objects velocity is constant.	Describe the motion of the object using the graph. Describe the trend in the graph. Describe the motion of the object between point A and B.
TKT A straight line with a positive gradient indicates the object is constantly accelerating (the velocity is increasing).	Describe the motion of the object between point C and D.
TKT A straight line with a negative gradient indicates the object is constantly decelerating.	Describe the motion of the object between point E and F. Explain the motion of the object using the graph. What does the horizontal line represent in a velocity-time graph?
TBAT Calculate the distance travelled by calculating the area under the graph.	Calculate the distance travelled using the graph.
TBAT Calculate the area of a triangle and rectangle.	Calculate the area of the triangle and rectangle.
TBAT Compare the features of a distance time graph with the features of the velocity time graph.	Compare the motion of the line in graph A and graph B.
TBAT Plot two variables from experimental or other data	Draw a suitable graph to display this data.
TKT Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.	Calculate the distance travelled by the object using the graph.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 11: Velocity- Time Graphs 2

Intended outcome	Example questions
TKT A curved line indicates the acceleration is changing.	Describe the motion of the object using the graph.
TKT The acceleration of an object can be found by calculating the gradient.	Describe how to calculate the acceleration from a curved graph.
TBAT Calculate the acceleration at a given time by using a tangent to the gradient.	Calculate the acceleration of the object at 12m's.
TBAT Calculate the speed of an object at a given time using a tangent to the gradient on a distance-time graph.	Calculate the acceleration of the object from the graph.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Science **Mastery**

Lesson 12: Acceleration Problems

Intended outcome	Example questions
TBAT Understand the relative magnitudes of forces acting on an object. TBAT Explain constant velocity.	Draw a free body diagram to represent the forces on the rocket. Explain the motion of the rocket. Describe the motion of the rocket in terms of velocity.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Mastery Quiz re-teach planning

To be completed once you have reviewed your pupils' response to the mastery quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout another unit? When will that be taught?

Other notes

Lesson 11: Feedback Lesson

Intended outcome	Example questions
Teacher can fill in this section based on mastery quiz feedback.	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Advanced subject knowledge

Where does this learning lead?

General mechanics

At A level students use their understanding of scalars and vectors to calculate forces acting at right angles and other angles. They use their GCSE understanding to describe the conditions for equilibrium for two or three coplanar forces acting at a point. They can apply this understanding experimentally by using apparatus such as a force board.

Linear motion

Students use their knowledge from GCSE on displacement, speed, velocity, and acceleration and apply the same equations from GCSE:

- Acceleration= change in velocity/time.

However, this is taken further at A level with application of the SUVAT equations.

- V=u +at
- V^2= U2 + 2as
- S=ut +1/2 at^2
- S=vt-1/2 at^2
- S=1/2(u+v)t

Where:

s- displacement
u- initial velocity
v- final velocity
a- acceleration
t- time

Projectile motion

Students then use the equations from the understanding of linear motion and apply this to the independent effect of motion in horizontal and vertical directions in a uniform gravitational field. This is used to explain qualitatively, the effect of air resistance on the trajectory of a projectile. This can be applied experimentally by investigating the factors that determine the motion of an object through a fluid.

Here students need to resolve the initial velocity into horizontal and vertical components using trigonometry. Using the vertical component of the initial velocity, students need to calculate the time taken for the projectile to return to the ground by using and applying an appropriate SUVAT equation. They should be able to apply the principle that acceleration is equal to gravitational field strength and apply the principle that at half the time taken for the projectile to return to the ground the final vertical component of the velocity is zero.

Newtons laws.

Students should recall and be able to apply all three of Newtons laws of motion from GCSE physics.

Have a look at the questions below and think about what this means for this unit.

How does learning from this unit develop at KS4?
What content from this unit is fundamental to student understanding at KS4?
How could you check that students have grasped these fundamentals?

Vocabulary and literacy

Tier 3 vocabulary and phrases in this unit that pupils are likely to already know:

Word	Definition	Example in context
Area	A two-dimensional quantity representing the amount of surface.	***Area*** *is measured in cm^2 or m^2*
Balanced	Equal in size and opposite in direction.	*When the forces acting on an object are **balanced**, the motion of the object does not change (if it was stationary, it will remain stationary and if it was moving it will continue to move at a steady speed in the same direction).*
Component	The horizontal or vertical part that makes up a diagonal vector.	*An object being pulled along the ground has a horizontal and vertical **component** to the force.*
Curve	A continuous and smooth flowing line without any sharp turns.	*A **curve** on a velocity-time graph shows that an object has a changing acceleration*
Distance	The length of a path or length between two points.	*The **distance** a person walks is 2 m.*
Gradient	The slope of a graph.	*The steeper the **gradient** of velocity-time graph, the greater the acceleration.*
Gravity	The force of attraction that exists between any two objects with mass.	***Gravity*** *is the force that attracts objects to the Earth.*
Slope	A measure of the steepness of a line. .	***Slopes*** *can be seen in velocity-time graphs*
Speed	The distance covered per unit time.	*An object that covers 10 metres in 10 seconds has a **speed** of 1 m/s.*
Stationary	Not moving. .	*A **stationary** object has a speed of 0 m/s*
Unbalanced	Forces that are not equal and opposite, a non-zero resultant force.	*An **unbalanced** force can change the shape, speed or direction of an object.*
Vertical	Perpendicular to an x-axis (an up or down line).	*Height is a **vertical** measurement.*
Weight	The force that acts on a mass due to gravity.	***Weight*** *is measured in Newtons.*

Tier 3 vocabulary that will need to be explicitly taught in context:

Word	Definition	Example in context
Acceleration.	The rate of change of velocity.	***Acceleration*** *is how quickly an object changes speed or direction.*
Action	A description of a change in a physical system.	*Newton's Third Law describes how every* ***action*** *has an equal and opposite reaction*
Constant velocity	When an object travels at the same speed in the same direction.	*The person walked with a* ***constant velocity*** *of 2 m/s East.*
Contact force	Is a force that acts when objects are physically touching each other. *Friction and air resistance are* ***contact forces***.	*Friction and air resistance are* ***contact forces***
Deceleration	Slowing down, also known as negative acceleration. ***Deceleration*** *involves a decrease in velocity.*	***Deceleration*** *involves a decrease in velocity.*
Displacement	The change in position of an object.	*The person's* ***displacement*** *was 3 m North of their original position.*
Final velocity	A vector quantity that describes the speed and direction of an object after an acceleration.	*If you drop a ball from a height, the velocity just before it hits the ground is the* ***final velocity***.
Force	A force is a push, pull or twist that can change the shape, speed or direction of an object.	*Weight and tension are examples of* ***forces***.
Friction	A contact force acting between two surfaces that are moving across or trying to move across each other.	***Friction*** *acts in the opposite direction to motion.*
Initial velocity	A vector quantity that describes the velocity of an object before an acceleration.	*If an object starts from rest then the* ***initial velocity*** *of the object is 0 m/s*
Mass	Mass is a measurement of how much matter is in an object.	***Mass*** *is measured in kilograms (kg).*

Non-contact force	A force which acts on an object over a distance. .	*Gravity is an example of a **non-contact force***
Resultant force	The sum of two or more vectors: the result of adding two or more vectors together.	*The **resultant** displacement is calculated from vectors*
Scalar	Quantities that have magnitude (size) only.	*Speed is an example of a **scalar**.*
Tangent	A straight line touching a curve at a single point without crossing the line.	*The acceleration can be found by calculating the gradient of a **tangent** to a curve*
Vector	Quantities that have both magnitude (size) and direction.	*Force is an example of a **vector** quantity, e.g. 5 N left.*
Velocity	The speed of an object in a given direction.	*An object has a **velocity** of 10 m/s to the left*

New scientists:

Scientist	**Famous for**	**Background**
Newton	✓ Inventing calculus and formulated the theory of universal gravity, ✓ Formulated the laws of motion. ✓ Invented the Newton telescope.	Isaac Newton (1642–1727) was an English physicist who attended Trinity college in Cambridge.
Galileo	✓ Acceleration due to gravity is independent of the objects mass.	Galileo Gallilei (1564 -1642) was an Italian physicist.

Appendices

Appendix 1: Mark scheme for pre-unit quiz

P3.1 Pre-Unit Quiz Mark scheme

Qu	Answer	Marks	Supporting information for fix-it tasks
1	B	1	Answering A is a common misconception that resultant force is always 0 because of forces cancelling each other out. Answering C is the misconception that resultant force is the largest force acting on an object. Task: *Practising calculating resultant force from diagrams and drawing free-body force diagrams to show directions of different forces.*
2	B	1	Answering A shows that pupils have correctly calculated the magnitude of the resultant force but incorrectly identified the direction. *Task: Practising calculations of resultant force with direction from free-body force diagrams.* Answering C shows that pupils have incorrectly added together forces acting in opposite directions. *Task: Practising calculations of resultant force with forces in the same direction and forces in opposite directions.*
3	C	1	Answering A or B shows a lack of understanding of the effects of unbalanced forces. Unbalanced forces can change the speed, direction or shape of an object so in this case the car's speed must be changing, meaning that it cannot be stationary or moving at a constant speed. *Task: Completing a summary to explain the effects of unbalanced forces on stationary objects and objects that are already in motion.*
4	A	1	Answering B or C shows a lack of understanding of the effects of balanced forces. An object will continue in its state of motion unless it is acted upon by an unbalanced force, so the car will continue moving at a constant speed as it was already in motion. *Task: Completing a summary to explain the effects of balanced forces on stationary objects and objects that are already in motion. Alternatively pupils could identify the motion*

			from free-body force diagrams and explain in terms of balanced and unbalanced forces.
5	B	1	Answering A shows an understanding of the equation but a lack of understanding about converting to SI units. *Task: Practise converting quantities to SI units in calculations.* Answering C shows an ability to convert into SI units but a lack of understanding of the speed – distance/time equation. *Task: Model how to lay out a speed = distance/time calculation for students to practice calculations, including rearranging for different unknown quantities.*
6	A	1	Answering B or C show a misconception of the meaning of a horizontal line on a distance-time graph and that pupils may have confused a positive gradient with a horizontal line. *Task: Pupils can be presented with different examples of distance-time graphs and asked to describe the motion at different stages. It may be useful to convert the graph into a table to show that no distance is being covered when there is a horizontal line.*
7	A	1	Answering B shows that pupils have confused a horizontal line with the steepest positive gradient. Answering C shows that pupils have understood that gradient represents speed but incorrectly interpreted the meaning of the steepness of the gradient. *Task: Pupils can compare the speeds of different sections of a distance-time graph and calculate the speed using the gradient to confirm their comparison.*
8	B	1	Answering A shows that pupils have extrapolated the maximum value from the y axis and taken this as the total distance. Answering C shows that pupils have added together the separate distance travelled at each point, rather than reading it as a cumulative value.

			Task: Pupils can work backwards to make a table of a distance-time graph or describe the journey shown by a distance-time graph in words.
9	A	1	Answering B or C shows that pupils have confused everyday units for speed with the SI unit. *Task: Pupils should revisit the SI units for distance and time and the equation that links speed, distance and time to show how the SI unit is derived.*
10	B	1	Answering A shows that pupils have calculated her speed for the first section of the run only, but correctly divided distance by time. Answering C shows that pupils have correctly identified that average speed is calculated from total distance divided by total time but they have neglected to include the time spent resting. This is a common misconception as some pupils will assume that this period of rest is not included in the calculation as her speed is 0 during this time. *Task: Pupils can be presented with other written scenarios to calculate average speed or they can calculate average speed for a whole journey from a distance-time graph.*

Appendix 2: Mark scheme for mastery quiz

P3.1 Mastery Quiz: Acceleration
Mark Scheme
Section A

Qu	Answer	Marks	Supporting information for fix-it tasks

1	B	1	Answering A or C shows a gap in knowledge about examples of vector and scalar quantities. *To fix it, reteach the difference between vectors and scalars and then give lots of quantities for students to sort into those two columns.*
2	A	1	Answering B shows a misconception that acceleration is an increase in speed. *To fix it, recap the definition of acceleration and then ask students to explain why acceleration is not just a change in speed.* Answering C shows that they have understood that acceleration is a vector quantity so involves a direction but that it does not necessarily have to be a change in direction to be acceleration. *Ask students to write their own definition for acceleration using the terms: speed and direction.*
3	B	1	Answering A shows a confusion with Newton's first law. *To fix it, reteach Newton's first and third laws and then ask students to write their own descriptions for each.* Answering C is shows a common misconception that stationary objects have no forces acting on them. *To fix it, ask students to describe the forces acting on a water bottle that is stationary on a table.*
4a	B	1	Answering A shows that students have correctly identified the direction of the resultant force but have not applied Newton's first law correctly – if an unbalanced force acts on an object, the object will accelerate in the direction of the resultant force. *To fix it, students may need further support to understand the difference between constant speed and acceleration.* Answering C shows that pupils have not understood that there is a resultant force and therefore have not applied Newton's first law. To *fix it, reteach Newton's first law and then ask students to explain why this object will not remain stationary in this example.*
4b	B	1	Answering A shows that students have understood that objects at constant speed will continue at that constant speed in the same direction but have not identified that this is an example of an unbalanced/non-zero resultant force. Answering C shows that pupils have identified the resultant force and its direction but not taken into account the original direction of the object. *To fix it, show students different scenarios, some stationary and some with constant speed in different directions and balanced or unbalanced forces to practice determining the resulting motion.*
5a	B	1	Answering A suggests that students have incorrectly applied the gradient rule from distance-time graphs and assumed that a lower gradient means a slower speed. *To*

			fix it, ask students to explain why the acceleration is greater at 10-20 seconds as compared to 30-40 seconds. Answering C suggests that students have confused velocity-time graphs with distance-time graphs and incorrectly identified a horizontal line as stationary. *To fix it, ask students to describe what a horizontal line represents in a D-T and a V-T graphs.*
5b	A	1	Answering B shows that pupils have confused the graph with a distance-time graph where it would be returning to its original position. It could not be travelling in the opposite direction unless it had a negative velocity (in the negative Y-axis), which pupils may need a reminder of. Answering C shows that pupils have identified relative gradients but misinterpreted this as speed rather than acceleration. *Pupils may find it useful to annotate a velocity time graph with the motion at each stage and calculate any possible values.*
5c	B	1	Answering A shows that students have just done the calculation of 10 x 30, which is the maximum velocity and the total time period, rather than the area under the graph. *To fix it, practice calculating area under the graph, particularly with different shapes (triangles/rectangles), although they are not expected to calculate area under a curve (i.e. where there is changing acceleration).* Answering C shows that pupils have calculated the total area under the graph, rather than just the first 30 seconds. This could be a case of pupils scanning questions too quickly. *To fix it, model how to underline/highlight the key information in a question and then ask students to underline the key information in all the questions.*
5d	A	1	Answering B shows that pupils have correctly used the gradient to calculate the acceleration but have given the SI unit for speed/velocity rather than acceleration. *To fix it, ask students to write out the SI units for: speed, acceleration, distance, time, mass, weight.* Answering C shows that pupils have used the correct unit for acceleration but have incorrectly calculated gradient as change in x/change in y. *To fix it, model how to calculate the acceleration for this question and then ask students to calculate the acceleration from 10-20 seconds showing their workings.*

			Answering D shows they have incorrectly calculated the gradient and chosen the incorrect unit. *To fix it model how to calculate the acceleration for this question and then ask students to write out how to calculate acceleration and to state the units.*
6	A	1	Answering B or C suggests a gap in knowledge about what the quantities in this equation are. *Reteach this equation and ask students to copy it in books, annotating what each part is.*
7	B	1	Answering A shows some understanding of the importance of using the correct equipment for accuracy, but it is not the cause of the anomaly. *To fix it, ask students to explain why option B could cause an anomaly. Then ask students to suggest an explanation if the anomaly was a much higher number.* Answering C suggests a gap in knowledge about what an anomaly is. *To fix it, model why the circled reading is indeed anomalous. Then ask students to explain why the circled anomaly should be excluded from the mean calculation.*
8	C	1	Answering A or B suggests a gap in knowledge about how to calculate acceleration. *To fix it, reteach how to calculate acceleration using a worked example and then ask students to answer other practice questions.*
9	B	1	Answering A shows that pupils know gradient is the change in x and y but have got these the wrong way round. Answering C or D shows that pupils do not understand how to work out the gradient of a specific part of a line rather than an average value for the whole graph. *To fix it, ask students to calculate the gradient of practice graphs, explicitly including the step change in y/change in x each time.*
10	C	1	Answering A suggests that students have understood that forces at right angles (or less) will produce a larger resultant force, but not that it will be smaller than if the forces were acting in the same direction. Answering B shows that students have not applied their knowledge to see that 180° means that forces would be acting in opposite directions and therefore would be subtracted from each other, making the minimum resultant force. *To fix it, students may find it useful to be given 2 forces and calculate the resultant in each case to show mathematically that forces acting in the same direction would cause the greatest resultant force because they would be added together.*
11	D	1	Answering A suggests that students have used the correct final velocity and the correct time but have not

			understood that 'rest' indicates an initial velocity of 0. Answering B suggests that students have incorrectly substituted the values for time and final velocity but have noticed that the initial velocity is 0. Answering C suggests that students have identified that rest is 0 m/s but incorrectly used this as final velocity rather than initial velocity. *To fix it, students may find it useful to be given calculation questions and highlight initial/final velocities, times and accelerations in different colours or underlined/circled etc to ensure that they substitute values into the correct place.*

Section B

Qu	Model answer	Supporting information *Suggestions for fix-it tasks*
1	distance, speed, mass or energy	Students may confuse scalars and vectors. *To fix it, reteach the difference between vectors and scalars and then give lots of quantities for students to sort into those two columns.*
2	Displacement is how far an object is from its original position or from a point of reference in a given direction.	A common error here is to not include the 'given direction' part of the definition. *To fix it, reteach the difference between displacement and direction and ask students why 2.4 km North is a measure of displacement and not distance.*
3	An object moving in a circle at constant speed is accelerating because acceleration is the change in speed or direction. This means that the object is accelerating because it is constantly changing direction.	A common misconception about acceleration is that it just refers to increasing speed, however it also includes changes in direction. *Using the information from this question, ask students to write their own definition for acceleration.*
4	See the graph below	This is a useful activity to identify which parts of a V-T graph students cannot deduce information about speed/acceleration. The most common error is to confuse the conventions of straight lines, gradients, and curves with that of D-T graphs. *To fix it, recap in a table what straight lines, gradients, and curves represent in D-T and V-T graphs and then ask students to annotate what is happening at each part of the graph in Q5.*

Appendix 3: Core knowledge statements

Forces

- A force is an interaction (e.g., push, pull or twist) between two objects.
- Contact forces are where the objects are physically touching, such as friction, air resistance, tension, and the normal contact force.
- Non-contact forces, where the objects do not have to be physically touching, such as magnetism, electrostatic force, and gravitational force
- Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth.
- The weight of an object depends on the gravitational field strength at the point where the object is.
- The weight of an object can be calculated using the equation: Weight (N)= mass (kg)× gravitational field strength (N/kg).

- Weight is measured using a Newton meter.
- Weight will change if the gravitational field strength changes, but mass will not.
- The resultant force is the net force acting on an object, or the overall effect of all the forces acting on an object.
- Balanced forces are when forces of the same magnitude act in opposite directions, cancelling each other out to produce a resultant force of 0 N

Speed

- Speed is how much distance is covered per unit time.
- The speed of an object can be calculated using the equation: $Speed\left(\frac{m}{s}\right) = \frac{Distance\ (m)}{Time\ (s)}$
- The SI unit for speed is m/s.
- A stationary object has a speed of 0 m/s.
- A distance-time graph can be used to describe an objects motion. •A horizontal line represents a stationary object.
- A straight line represents an object moving at the same speed.
- A curved line describes an object accelerating.

Scalars and Vectors

- Scalars are quantities which only have size.
- Vectors are quantities with size and direction
- Examples of scalars include distance, speed, mass, and energy.
- Examples of vectors include displacement, velocity, acceleration, force, weight, and momentum.
- Velocity is speed in each direction.
- Displacement is how far an object is from its original position or from a point of reference in a given direction.
- A resultant vector is the combination of two or more single vectors, such as resultant force.
- Vectors acting in the same direction can be added together.
- Vectors acting in opposite directions can be subtracted.
- The resultant of two vectors at right angles to each other can be determined by calculation or by scale drawing.
- A single force can be resolved into two components acting at right angles to each other. The vertical and horizontal component forces together have the same effect as the single force.

Newton's Laws

- Newton's Third Law states that every action has an equal and opposite reaction
- This means that if object A exerts a force on object B, object B exerts an equal and opposite force on object A.
- Newton's First Law states that an objects motion will not change unless acted on by an unbalanced force (non-zero resultant force).
- An object is in equilibrium if the forces acting on it are balanced, and the resultant force is 0 N.
- A stationary object will stay stationary if the resultant force is 0N.
- An object in motion will stay moving at the same velocity if the resultant force is 0N.
- A stationary object will accelerate in the direction of the force if the forces are unbalanced.
- A moving object will accelerate in the direction of the resultant force.
- The tendency of objects to continue in their state of motion is called inertia.

Acceleration

- Acceleration is the rate of change of velocity.
- Acceleration is a measure of how quickly an object speeds up, slows down, or changes direction.
- An object moving in a circle is constantly changing direction, therefore it is accelerating.
- A negative acceleration, or slowing down, can be called deceleration.
- The SI units of acceleration are (m/s2).
- Near the Earth's surface any object falling freely under gravity has an acceleration of about 9.8 m/s2.
- Air resistance/drag increases with speed.
- The acceleration of an object can be calculated using the equation:
  $Acceleration \frac{Change\ in\ velocity}{Time}$
- The change in velocity can be calculated using the final velocity minus the initial velocity.
- Velocity-time graphs can be used to describe motion.
- A horizontal line indicates the objects velocity is constant.
- A straight line with a positive gradient indicates the object is constantly accelerating (the velocity is increasing).
- A straight line with a negative gradient indicates the object is constantly decelerating.
- The distance travelled can be found by calculating the area under the graph.
- A curved line indicates the acceleration is changing.
- The acceleration of an object can be found by calculating the gradient.

Disciplinary Knowledge

62. Understand that y=mx + c represents a linear relationship
66. Change the subject of an equation
69. Determine the slope and intercept of a linear graph
71. Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.
79. Any anomalous values should be examined to try to identify the cause and, if a product of a poor measurement, ignored.
96. Recognise the importance of scientific quantities and understand how they are determined.

Practical Skills
26. Measure time accurately
47. Measure motion, including determination of speed and rate of change of speed (acceleration/deceleration)
59. Plot two variables from experimental or other data.