BIG IDEA:	**Forces predict motion**
Prior Learning:	**P1.1 Forces** • Forces have size and direction • Forces are represented on free-body force diagrams using arrows to show the direction and size of the force. • An objects motion does not change if forces are balanced. • Balanced forces are equal in size but opposite in direction. • An unbalanced force can change an objects shape, speed or direction • The resultant force on an object is the net force. • When forces are balanced there is a 0N resultant force. • When forces are unbalanced the resultant force is not 0N **P1.2 Space** • Mass is the amount of matter contained in an object and is measured in kg. • Weight is the force of gravity acting on a mass is measured in Newtons. **P2.1 Movement and Pressure** • Speed is how much distance is covered in a given time. • Speed = distance / time • The SI unit for speed is m/s. • If an object is stationary its speed is 0 m/s. • Average speed is the overall distance travelled divided by the overall time for a journey • Acceleration describes how quickly a speed is changing (speeding up or slowing down). • 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. • Describe an object's motion from a graph.
Future Learning:	Key concepts from this unit provide a basis to further understanding of forces and motion, including other methods of calculating acceleration, terminal velocity and safety features of cars. Pupils will also build on their understanding from these concepts at A-Level where they will calculate the components of weight for objects on a slope, as well as building their graphing skills to include acceleration-time graphs. They will also be required to understand graphs of motion for vertical motion and projectile motion. These concepts form the basis of degrees and careers in fields such as engineering and mechanics.
Key misconceptions:	Pupils may still be holding onto misconceptions about forces from previous units, most commonly that stationary objects have no forces acting on them rather than a zero resultant force. Some pupils may still be struggling with the theory behind Newton's First Law and be unable to explain why an object in motion continues in its state of motion if the forces acting on it are balanced. This links with another misconception around Newton's First Law where pupils assume that unbalanced forces only cause objects to accelerate in the direction of their original motion. A common misconception with Newton's Third Law is that pupils will see the phrase equal and opposite and assume that means the forces cancel each other out, meaning they are unable to understand why objects are able to move at all. It can be useful to use free-body diagrams when explaining Newton's Third Law to ensure that pupils recognise the equal and opposite forces are acting on different objects. Another common misconception in this unit is that pupils assume acceleration always refers to speeding up and are not very good at actually estimating what acceleration looks like (e.g. if they are asked to show it by accelerating from rest). Some pupils may also still hold the misconception that an applied force constantly acts on an object until it 'runs out'. Pupils should be secure with their understanding of distance-time graphs in order to access velocity-time graphs otherwise they can develop misconceptions around the meaning of horizontal lines and positive gradients.
Unit sequencing:	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 Pythagoras's theorem and trigonometric ratios, as well as by construction of scale diagrams. These are introduced very simply in this context, as not all pupils may have covered these topics 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

Unit title	Lesson code	Lesson title	What do my students need to <u>know</u> by the end of the lesson?	Spec references	What could help my students to understand this knowledge?	What do my students need to be able to <u>do</u> by the end of the lesson?	What <u>prior knowledge</u> do I expect my students to have? Where is this likely to have come from?	What practical activities are planned? *What apparatus and chemicals are required?*	What are the <u>core practical, enquiry and maths skills</u> that students will learn and practise? Key: Skills in **bold** are taught for the first time here	What <u>misconceptions</u> may students arrive at the lesson with? What could they leave the lesson thinking if we are not careful? How can I address this directly? NOTE: More misconceptions are	What <u>exit ticket questions</u> will the students be required to answer by the end of the lesson?	What <u>alternative activities</u> could I do in this lesson?	What <u>keywords</u> am I introducting in this lesson that students may find difficult?
	P3.1.1	**Prior knowledge Review**	• 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 Newtometer • 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 is how much distance is covered per unit time • The speed of an object can be calculated using the equation: Speed (m/s)= (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.			• Define speed. • State the equation that links speed, distance and time. • Calculate speed, distance and time. • Calculate average speed during a journey. • Identify the forces acting on different objects. • Draw free-body force diagrams. • Calculate the weight of an object. • Explain the difference between mass and weight. • Explain what is shown by the slope on a distance-time graph. • Use the gradient of a distance-time graph to calculate speed. • Compare speeds on a distance-time graph using slopes • Explain what is shown by a horizontal line, a curved line and a line returning to the origin on a distance-time graph.	**Pupils should have covered P1.1, P1.2 and P2.1. They should be secure with balanced, unbalanced and resultant forces, calculating speed and using distance-time graphs.**			**Biggest misconception that pupils have from earlier topics is that if an object is stationary it means no forces are acting on it, rather than the forces being balanced. It may be useful to remind pupils that just because an object is not moving it does not mean there are no forces acting - e.g. a book resting on a table still has weight and therefore it must have a reaction/normal force from the table to keep it stationary.**	**1. Which is the best definition of resultant force? A.When the forces acting on an object cancel each other out B. An interaction between two objects C. The net force acting on an object 2. The speed of a car that travels 100 metres in 5 seconds is… A. 20 m/s B. 0.05 m/s C. 500 m/s 3. A horizontal line on a distance-time graph represents… A. An object moving at constant speed B. An object accelerating C. A stationary object**	**Complete the pre unit quiz to identify gaps from previous units. Suggested fix-it activities can be found in the mark scheme.**	**Force, contact, non-contact, resultant, friction**
	P3.1.2	**Scalars and Vectors**	• Examples of scalars include distance, speed, mass and energy • Examples of vectors include displacement, velocity, acceleration, force, weight and momentum • Velocity is speed in a given direction • Displacement is how far an object is from its original position or from a point of reference in a given direction	6.5.1.4, 6.5.4.1.1, 6.5.4.1.2, 6.5.4.1.3	When reporting any quantities units should be used and when vectors are reported they must have a direction. This is one of the most common and easiest marks lost in GCSE exams where pupils are simply not in the habit of writing directions with their vector quantities so it is good practice to get them used to it as you introduce it.	• Define scalar and vector quantities. • Give examples of scalar and vector quantities. • Explain the difference between speed and velocity. • Explain the difference between distance and displacement. • State that vector quantities can be represented with arrows that are proportional to their magnitude and show the direction of their action.	Pupils should be confident with definitions of speed and distance and confident using the speed = distance/time equation, and with allocating directions to forces (e.g. gravity)			This can be a good opportunity to check for the mass vs weight misconception as pupils may still be carrying this from P1.2. Mass is the amount of matter in a substance so is a scalar quantity, whereas weight is the effect of gravity on the mass, acting towards the Earth so it is a vector quantity with a direction.	1. Velocity is a vector quantity because… A. It is has size and direction B. It has size only C. It is how much distance is covered in a given time 2. If a person walks 4 m left then 8 m right… A. Their displacement is 12 m right B. Their displacement is 4 m right C. Their displacement is 4 m left 3. What would the velocity of the person in Q2 be if they completed these movements in 8 seconds? A.1.5 m/s right B. 0.5 m/s C. 0.5 m/s right		scalar, vector, speed, velocity, displacement, distance
	P3.1.3	**Resultant Vectors**	• 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	6.5.1.4	This lesson includes 2 skills which pupils generally find difficult - scale drawings and resolving vectors into components, both of which are higher tier skills only. The focus of this lesson is a basic introduction to these two skills but you may find that pupils need a lot more practice to be able to confidently complete questions, in which case you may want to split this lesson into two.	• Calculate resultant force acting on an object • Resolve a resultant vector acting at an angle into its horizontal and vertical components	Pupils should be confident with calculations of resultant vectors when vectors are acting in the same direction and in opposite directions	You may want to demonstrate two pupils pushing or pulling an object at right angles to each other to show that the resultant force will end up between them.		If pupils do not use the tip to tail method they will calculate the correct value for the resultant force but it will be pointing in the wrong direction. It can be useful to get two people pulling on an object, one up and one sideways, to show that the resultant would be in between those forces, which can only happen if the tip to tail method is followed.	1. Diagonal vectors can be resolved into… A. Two components acting at right angles to each other B. Two components acting at 0° to each other C. Two components acting at 180° to each other 2. A diagonal vector of magnitude 12 N could be made up of… A. Two 6 N components B. An 18 N and a 6 N component C. Two 8.5 N components 3. Which is an essential aspect to include in a scale drawing? A. Lines drawn in pen B. A scale	Pupils can be given diagonal resultant vectors to resolve into components, then construct a scale drawing using the components to confirm calculations.	resultant, component

	P3.1.4	**Resolving Vectors**	• 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	6.5.1.4		• Determine a resultant vector using a scale diagram							
	P3.1.5	**Newton's Third Law**	• 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	6.5.4.2.3	Newton's Third Law can also be stated as "If Object A exerts a force on object B, object B will exert an equal and opposite force on object A".	• State Newton's Third Law • Draw free-body force diagrams • Use Newton's Third Law to explain why an object will move	Pupils should be able to confidently draw free-body force diagrams and know the names and definitions of a number of common forces.			Di Sessa (1993) - pupils will see the phrase equal and opposite and assume that means the forces will cancel out (i.e. there will be no resultant force) which is then hard to explain why any objects can move at all. It may be useful in all examples used to draw separate free body diagrams for the two objects involved to show that the action-reaction pair is not acting on the same object. A useful example to discuss is a person jumping off a skateboard, where pupils can clearly see the person jumping foward and the skateboard moving backwards, because they have exerted equal and opposite forces on each other.	1. Newton's Third Law states that … A. Objects will exert equal and opposite forces on each other than will cancel out B. If an object exerts a force on another it will exert the same force C. Every action has an equal and opposite reaction 2. The reaction force to the weight of an object resting on a table is… A. The force of gravity on the object B. The normal force exerted by the table on the object C. The weight of the table 3. If a large person and a small person bump into each other what can be said about the forces they exert on each other? A. The large person will exert a larger force B. The small person will exert a larger force	Science in the News activity	action, reaction
	P3.1.6	**Newton's First Law**	• 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 0 N • An object in motion will stay moving at the same velocity if the resultant force is 0 N • 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	6.5.4.2.1	Many textbooks and resources will refer to objects moving in the direction of the resultant force rather than accelerating in the direction of the resultant force. Although this seems fine for objects that are initially stationary, it is more accurate to say that they accelerate in the direction of the resultant force. From P1.1 pupils will have learnt that unbalanced forces can change the speed so using the term acceleration builds on this understanding.	• Define inertia • State the resultant force acting on an object at equilibrium • Describe the possible effects of unbalanced forces • Determine the motion of an object from the forces acting upon it	Pupils should be able to calculate resultant force and determine the direction of the resultant force	Model with a toy car and force diagrams at each stage, or suggested demo from IOP (in alternate activities).		Liu et al (2016) - pupils will assume that acceleration is always in the direction of motion, i.e. that if the acceleration is negative they will assume that it means the object has changed direction and is now going to other way, rather than slowing down in the original direction. A good example to use to combat this misconception is with the brakes in a car. If the thrust force is greater than the braking force/air resistance the car will accelerate forwards. If the braking force is greater than the thrust force the acceleration will be in the opposite direction, which means it has a negative acceleration in the original direction (the car will slow down) but it will not be going in the opposite direction because it is not in reverse.	1. Newton's First Law states that … A. Objects' motion will not change unless acted upon by an unbalanced force B. Objects will remain stationary if they are acted upon by an unbalanced force C. Every action has an equal and opposite reaction 2. An object that is moving at 0.5 m/s to the right is acted upon by a resultant force of 5 N left. Which best describes its resulting motion? A. It will move at 0.5 m/s to the left B. It will now be stationary C. It will slow down but continue moving towards the right 3. Which of these resultant forces would cause a stationary object to accelerate to the left? A. 0 N B. 5 N left C. 5 N right	Suggestion for a demonstration or practical: https://spark.iop.org/newtons-first-law-demonstration#gref	balanced, unbalanced, resultant, stationary, constant velocity
3.1 Acceleratio	**P3.1.7**	**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 (m/s^2)= (Change in velocity (m/s))/(Time (s)) • The change in velocity can be calculated using the final velocity minus the initial velocity	6.5.4.1.5	Pupils have learnt in P1.1 that unbalanced forces can change the speed of an object but almost all pupils will assume that acceleration refers to an obejct speeding up. Pupils can refer to slowing down as deceleration or negative acceleration for equal credit but they need to be aware that acceleration can refer to speeding up, slowing down or changing direction. A common mistake in GCSE exams is not being able to explain why an object travelling in a circle (e.g. orbiting) is always accelerating.	• Define acceleration • Explain how an object moving in a circle is accelerating • State the equation to calculate acceleration • Calculate change in velocity • Describe the effect of increasing velocity on resistive forces • State the initial velocity of an object that starts from rest • Calculate acceleration from the equation • Relate changes in distance covered per unit time to acceleration of an object • Describe and explain the forces acting on an object that is accelerating	From P2.1 pupils should be able to recognise the difference between stationary objects, objects that are travelling at a constant speed and objects that are accelerating or hanging speed.	Get pupils to model acceleration in the classroom (or in the playground for more room). It is interesting to note that pupils understand that they know they should be getting faster but usually accelerate quickly at the start then move/walk at a constant speed.	96. Recognise the importance of scientific quantities and understand how they are determined. 66. Change the subject of an equation	Driver et.al (1994) - pupils tend to think of accelerating objects having a constant force applied rather than just being applied once and will assume that if the force is only applied at the start that it will run out, rather than just stopping because of friction acting on it. It can be useful to use an example in space (such as in one of the blockbuster films) where an astronaut is accidentally pushed away from a space station (initial force) and continues moving in a straight line at the same speed. Dykstra and Sweet (2009) found that children are very poor at estimating acceleration and when told to start slowly and speed up steadily they either walked at a constant speed or had a point where they sped up. It may help pupils to grasp acceleration by putting numerical values into an example - i.e. after 1 second I am walking at 2 m/s, after 2 seconds I am walking at 4 m/s, so they can see the steady increase in velocity.	1. Acceleration is … A. Rate of change of velocity B. When an object gets faster C. An increase in velocity 2. Which of these is an example of acceleration? A. A car coming to a stop at traffic lights B. A car driving over the speed limit at 20 m/s C. Two trains passing each other at different speeds 3. What is the acceleration of a sprinter going from rest to 10 m/s in 2 seconds? A. 5 m/s B. 5 m/s2 C. - 5 m/s2		acceleration, deceleration, velocity, initial velocity, final velocity
	P3.1.8	**Acceleration Investigation**		6.5.4.1.5	This is the required practical for Newton's Second Law, which is not covered in this unit. It investigates the relationship between force, mass and acceleration but for the purpose of this unit the focus is on the practical skills needed to calculate acceleration using initial and final velocity.	• Measure initial and final velocity	Pupils need to be able to use speed = distance/time to calculate the final velocity of the toy car/trolley	Required Practical Activity 7 (Physics only) and 19 (Trilogy): Investigate the effect of varying the force on the acceleration of an object of constant mass and the effect of varying the mass of an object on the acceleration produced by a constant force.	26. Measure time accurately 47. Measure motion, including determination of speed and rate of change of speed (acceleration/deceleration) 79. Any anomalous values should be examined to try to identify the cause and, if a product of a poor measurement, ignored.		1. What was the dependent variable in this experiment? A. Force applied B. Mass of the car C. Acceleration 2. Acceleration can be calculated by… A. change in velocity divided by time B. distance divided by time C. velocity divided by time 3. An object accelerates from rest to 10 m/s in two seconds. What is its initial velocity? A. 2 m/s B. 10 m/s C. 0 m/s		force, mass, acceleration, initial velocity, final velocity

	Maths in Science Lesson 17	**Linear Graphs**							**62. Understand that y=mx + c represents a linear relationship** **69. Determine the slope and intercept of a linear graph**				
	P3.1.9	**Velocity-Time Graphs**	• Velocity-time graphs can be used to describe motion. • A horizontal like 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.	6.5.4.1.5	It is useful for pupils to be able to recall the equations to calculate area of a rectangle and area of a triangle for calculating area under the graph.	• Compare the features of a distance-time graph with the features of a velocity-time graph (horizontal line, gradient) • Identify constant speed on a velocity-time graph • Calculate the distance travelled using the area under a velocity-time graph	Pupils need to be secure in their understanding and application of distance-time graphs, which you can gauge from the prior knowledge activity or pre test. They should be confident with the meanings of the gradients/horizontal line and how to calculate the gradient.		59. Plot two variables from experimental or other data. **71. Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.**	Lingefjard & Farahani (2018) - pupils tend to confuse the idea of horizontal lines and slopes/gradients. It can be useful to use dual coding during your explanation of the features of the graph so they can see what you are referring to when you say horizontal line and positive/negative gradient.	1. What does a horizontal line represent on a velocity-time graph? A. Constant velocity B. A stationary object C. Increasing velocity 2. What can be calculated from the area under a velocity-time graph? A. Distance travelled B. Average velocity C. Total time taken 3. What does a negative gradient represent on a velocity-time graph? A. An object stopping B. An object returning to its original position C. An object slowing down		velocity, acceleration, gradient, slope, area
	P3.1.10	**Velocity-Time Graphs 2**	• A curved line indicates the acceleration is changing. • The acceleration of an object can be found by calculating the gradient.	6.5.4.1.5	It may be useful for pupils to see that the method for calculating instantaneous speed is the same as the method for calculating acceleration at a point, just on different graphs. Many will need support with getting the tangent in the correct place, but answers for these calculations have more room for error than other calculations.	• Calculate the acceleration at a given time by using a tangent to the gradient • Calculate the speed of an object at a given time using a tangent to the gradient on a distance-time graph					1. What can be calculated from the gradient of a velocity-time graph? A. Distance travelled B. Acceleration C. Velocity 2. What does a curved line represent on a velocity-time graph? A. Constant velocity B. Constant acceleration C. Changing acceleration 3. Which of these would not have a negative value for acceleration? A. An object speeding up in the opposite direction B. An object slowing down C. An stationary object		curve, gradient, tangent
	P3.1.11	**Acceleration Problems**			This lesson introduces pupils to vertical motion, which is a concept studied in much greater detail at A-level, although here there is not much new information introduced, it is just application to a different context. It may be useful to draw free body diagrams for pupils at each point in the rocket's journey so they are able to understand the relative magnitudes of the forces. You may want to use a video clip of a rocket launching so pupils can visualise the forces acting.		Pupils need to be secure with the meanings of features on a velocity-time graph and be able to explain constant velocity and acceleration in terms of balanced and unbalanced forces.			Hast and Howe (2013) - study with balls in free fall, accelerating down a ramp and rolling down a flat surface, with pupils asked to identify if they were speeding up, slowing down or at constant speed. Pupils were very poor at identifying that a ball rolling along a surface is slowing down and struggled to identify that an object accelerates during free fall. It may help to actually show pupils these examples and then use free body diagrams to explain why the ball slows down on a table and why it accelerates when in free fall.	1. Which scenario would have a non-zero resultant force? A. An object travelling at constant velocity B. A stationary object C. An object decelerating 2. At what point would a rocket have a velocity of 0? A. Just before it hits the ground B. At its highest point C. Just after it takes off 3. Which would show an object decelerating on a velocity-time graph? A. A negative gradient B. A positive gradient C. A horizontal line at 0 on the y axis	Further practice of acceleration calculations.	vertical, gravity, weight, resultant, acceleration
	P3.1.12	**Feedback Lesson**									1. Acceleration is … A. An increase in velocity B. A change in speed C. A change in velocity 2. An object that was moving at a constant speed towards the right is acted upon by a resultant force of 50 N right. The object will… A. Accelerate towards the right B. Accelerate towards the left C. Slow down to a stop 3. What is the acceleration of a car that goes from rest to 15 m/s in 10 seconds? A. 0.67 m/s2 B. 1.5 m/s2 C. -1.5 m/s2		