Cambridge Assessment International Education

St Peters College

Mechanics

Version 2

Cambridge Pathway

Contents from Cambridge

Teaching order and principals

The first 5 chapters and the idea of this entire module is that all the concepts and methods link into one another. You will see questions in Chapter 5 that have methods from the previous first 4 chapters. It is essential you follow an order that allows this to happen and interweave your teaching. You will find the SOW below does this also so please read all objectives carefully.

Understanding the idea of there being chapters that link with each other and those are separate, gives you an idea of the structure of the exams.

Topic 1	Kinematics Part 1	Speed, distance and time graphs	Chapter 1	https://www.mathsgenie.co.uk/resources/as-mechanics-velocity-time-graphs.pdf
Topic 2	Kinematics Part 2	SUVAT	Chapter 1	https://www.mathsgenie.co.uk/resources/as-mechanics-suvat.pdf
Topic 3	Forces Part 1	Resultant forces, splitting into horizontal and vertical	Chapter 3	
Topic 4	Forces Part 2	Forces acting on smooth surfaces.	Chapter 2	
Topic 5	Forces Part 3	Friction	Chapter 4	https://www.mathsgenie.co.uk/resources/a-mechanics-resolving-forces.pdf

				https://www.mathsgenie.co.uk/resources/a-mechanics-resolving-dynamics.pdf
Topic 6	Connected Particles	Part of the Forces content	Chapter 5	https://www.mathsgenie.co.uk/resources/a-mechanics-connected-particles.pdf https://www.mathsgenie.co.uk/resources/as-mechanics-f-m-a.pdf
Topic 7	Kinematics Part 3	Calculus and Kinematics.	Chapter 6	https://www.mathsgenie.co.uk/resources/a-mechanics-vectors-calculus.pdf
Topic 8	Momentum		Chapter 7	
Topic 9	Work and Energy		Chapter 8	
Topic 10	The Work Energy Principal and Power		Chapter 9	

Guided learning hours

Topic op	Suggested teaching time (hours)	
4.1 Forces and equilibrium	It is recommended that this should take about 20 hours.	
4.2 Kinematics of motion in a straight line	It is recommended that this should take about 12 hours.	
4.3 Momentum	It is recommended that this should take about 6 hours.	

Topic op	Suggested teaching time (hours)	
4.4 Newton's laws of motion	It is recommended that this should take about 10 hours.	
4.5 Energy, work and power	It is recommended that this should take about 12 hours.	

Prior knowledge

Questions set will be mainly numerical, and will aim to test mechanical principles without involving difficult algebra or trigonometry. However, candidates should be familiar in particular with the following trigonometrical results:

$$\sin(90^\circ - \theta) \equiv \cos\theta \ , \ \cos(90^\circ - \theta) \equiv \sin\theta \ , \ \tan\theta \equiv \frac{\sin\theta}{\cos\theta} \ , \ \sin^2\theta + \cos^2\theta \equiv 1$$

Knowledge of algebraic methods from the content for Paper 1: Pure Mathematics 1 is assumed.

Resources

You can find the endorsed resources to support Cambridge International AS & A Level Mathematics on the Published resources tab of the syllabus page on our public website here.

Endorsed textbooks have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. All textbooks endorsed by Cambridge International for this syllabus are the ideal resource to be used alongside this scheme of work as they cover each learning objective. In addition to reading the syllabus, teachers should refer to the specimen assessment materials.

Lesson	Objectives	Textbooks	Notes
1 Introduction to Mechanics	Understand the idea of mathematical modelling of	Not in Text book	You may like to demonstrate some surprising phenomena which can be modelled with simple maths: - a small ball held on top of a larger ball, then both dropped together (the small ball bounces very high) - a full can and an empty can rolling downhill – which arrives first?

	real-life situations. Understand common words used in Mechanics (see Notes).		- stand on bathroom scales and press down with broom on scales, or on floor – how does this affect the reading on the scales? (apparatus available from Science) Students could try the experiment in NLM page 8, 13 or 14. Introduce basic definitions: - particle is an object whose size is negligible – if we model an object as a particle then we ignore its shape, rotation and air resistance; - light means having negligible weight; - smooth means no friction; - uniform means not changing; - kinematics is the study of movement (how things move) - dynamics is the study of what makes things move (i.e. forces, momentum).

	● use the relations hip between mass and weight; $W = mg$; in this component, questions are mainly numerical, and use of the approximate numerical value 10 (ms^{-2}) for g is expected.	Make sure that learners are familiar with the instruction on the front of the exam paper to use 10 ms^{-2} as the acceleration due to gravity. Many learners will come across other values, for example in their study of Physics. Some good ideas for practical work and discussions concerning acceleration due to gravity, and how to obtain the force of weight from a known mass are at: www.cimt.org.uk/projects/mepres/alevel/mechanics_ch2.pdf Past/specimen papers and mark schemes are available to download at www.cambridgeinternational.org/support This objective is covered extensively in questions listed under the vertical motion and motion on an inclined plane objective (see later).	
	● solve simple problems which may be modelled as the motion of a particle moving vertically or on an inclined plane with constant acceleration; including, for example, motion of a particle on a rough plane where the acceleration while moving up the plane is	This short video clip shows clearly how to analyse the forces on an object moving on an inclined plane: www.youtube.com/watch?v=dA4BvYdw7Xg	

	different from the acceleration while moving down the plane.		
	• solve simple problems which may be modelled as the motion of connected particles, e.g. particles connected by a light inextensible string passing over a smooth pulley, or a car towing a trailer by means of either a light rope or a light rigid towbar.	Discuss the significance of the modelling assumptions here: ‘smooth’ peg or pulley implies constant tension along the length of the string, and ‘light inextensible string’ implies that the connected particles have identical acceleration. Helpful notes, examples and questions are at: www.mathcentre.ac.uk/resources/uploaded/mc-web-mech2-12-2009.pdf **(I)** www.examsolutions.net provide a number of video tutorials on vertical strings over a smooth pulley, and inclined planes including when one is not vertical.	

4.2 Kinematics of motion in a straight line

Learning objectives	Suggested teaching activities	
• understand the concepts of distance and speed as scalar quantities, and of displacement, velocity and acceleration as vector quantities; restricted to motion in one dimension only; the term 'deceleration' may sometimes be used in the context of decreasing speed.	Reiterate the difference between scalar and vector quantities. In one dimension, the direction of a vector will determine whether you use a positive or negative sign. Give a few simple examples. Stress that negative speed or distance is incorrect. Also make sure that learners understand that a negative acceleration is equivalent to a positive deceleration.	Kinematics exam https://www.drfrostmaths.com/worksheets.php?wid=23982
• Part 1 Velocity, distance time graphs • sketch and interpret displacement–time graphs and velocity–time graphs, and in particular appreciate that: - the area under a velocity–time graph represents displacement - the gradient of a displacement–time graph represents velocity - the gradient of a velocity-time graph represents acceleration.	A summary of the key points for the two types of graphs, with a few questions, is at: www.mathcentre.ac.uk/resources/uploaded/mc-web-mech1-10-2009.pdf A more complete discussion, with extensive examples and questions, is at: www.cimt.org.uk/projects/mepres/alevel/mechanics_ch2.pdf (This includes the calculus aspect and the equations of motion for constant acceleration, as well as a treatment of the forces involved in changing the motion of an object.)	Make sure pupils can calculate using trapeziums and not break graphs down. Make sure your do examples of vehicles over taking one another. Find Time that they overtake if started at different points or times
• Part 2 SUVAT • use appropriate formulae for motion with constant acceleration in a straight line; questions may involve setting up more than one equation, using information about the motion of different particles.	The document mentioned above (www.cimt.org.uk/projects/mepres/alevel/mechanics_ch2.pdf), demonstrates the derivation and use of the formulae, as well as providing questions for learners to try for themselves. **Extension activity:** Challenge learners to derive the formulae, perhaps giving them a few hints. They could start from the basic definition of constant	Need to do multistep SUVAT. Where V1 = U2 Make sure you calculate diving board questions using negative displacement Essential that questions are completed with algebraic answers only.

Learning objectives	Suggested teaching activities	
	acceleration as the difference in velocities per second, or from their understanding of acceleration as the gradient of a velocity-time graph. A video with a straightforward example demonstrating very clearly the use of the formulae (sometimes known as 'suvat' equations, named after the five variables involved) is at: www.youtube.com/watch?v=jfOSQBB7Bhs. It is particularly important to make clear to learners that these formulae can only be used in cases where the acceleration is constant, not where acceleration varies with time. It is also important that learners have experienced, and discussed the relevance of, cases where the time has to be found from a quadratic equation, giving two solutions. Give learners a wide variety of questions requiring them to use the equations of motion, e.g. from textbooks and at the links above.	
• Part 3 Kinematics with calculus. • use differentiation and integration with respect to time to solve simple problems concerning displacement, velocity and acceleration; calculus required is restricted to techniques from the content for Paper 1: Pure Mathematics 1.	The document mentioned above (www.cimt.org.uk/projects/mepres/alevel/mechanics_ch2.pdf) has a good explanation of the use of differentiation and integration in the context of displacement, velocity and acceleration. It is worth spending time on examples that require learners to find constants of integration.	Make sure examples of multistep graphs are used. Having different domains and equations for int or diff are good questions and need to be asked. Make sure pupils understand all the concepts and words surrounded with the constant of integration. For example, the effects of starting from rest or 10m from the origin. Test https://www.drfrostmaths.com/worksheets.php?wid=48327
•		

Motion Graphs 1	Understand what displacement means, as distinct from distance. Draw and interpret distance-time graphs and displacement-time graphs – including being able to find speed or velocity from the gradient.	EX1D and 1 E Graphs and SUVAT equations are interweaved. You may want to do this separately.	This is an easy topic that they have covered before but students need to understand the basics of kinematics. They learn about displacement and velocity as the lead-in to acceleration, which will bring us back to Newton's second law, F = ma. They also apply their skills with vectors in kinematics. First we look at distance-time graphs, and then displacement-time graphs, which students often struggle with. They learn that the gradient of a displacement-time graph is the velocity (and of a distance-time graph is the speed). Introduce notation: - *t* for time - *s* for distance - *s* or *x* for displacement (or sometimes *h* in the case of vertical displacement) Students need to be clear that to measure displacement, you have to fix a zero point, or origin, from which all displacements are measured. You also have to decide which direction will be represented by positive displacements and which by negative; conventionally, up or right are usually positive and down or left negative. It is possible to go a long distance and yet finish with zero displacement, if you end up at the point where you started.
17 Kinematics Formulae 1	Rearrange and substitute into formulae.	MST: p. 7, Review Q. 1 – practice on rearranging and substituting into formulae. If extra practice is needed, either make up your own questions or use a pdf alt txt book	Students need to be confident and quick at rearranging formulae, and substituting into them. They may well find this difficult even for very simple formulae, and will need to be taught a system. (Either: treat the equation like a pair of scales, and do whatever you like as long as you do it to both sides to keep it balanced; or let them use the idea of moving terms from one side to the other and changing the sign from positive to negative, or divide to multiply, etc. The former way of thinking is more 'correct', but some students are in the habit of using the latter and have become comfortable with it.) (This should of course also be covered in Pure Maths.) Extra resource: Rearranging Formulae Practice.
18, 19 Kinematics Formulae 2 and 3 (2 lessons)	Use the equations of constant acceleration (note: the first needs to be	Again SUVAT is interweaved in the book EX 1D and E	Make sure students understand that these equations apply when the acceleration is constant – if the acceleration is varying, things become more complicated (and need to be dealt with using calculus). Also, they must not use the constant-velocity equation v = s / t when there is acceleration – students often try to!)

	memorised, while the other two are given in the exam): $a = (v - u) / t$ $s = ut + ½ at^2$ $v^2 = u^2 + 2as$ where: u = initial speed, v = final speed.		Students may encounter the additional equation $s = ½ (u + v)/t$. It is not essential to memorise this, as it is simply a combination of two of the equations on the left. Then again, it can be useful and has the advantage that it is fairly easy to understand intuitively. Get students into the habit of approaching kinematics questions in a systematic way, e.g.: 1. You are always considering a journey, or section of journey, of a body. The journey has a start and end point, a total distance travelled, a start and end speed, and a constant acceleration throughout. It may be, say, a ball travelling from the ground to its maximum height, or a car decelerating to a halt at traffic lights, or a defined subsection of some longer journey. The speed at the start is represented by u and the speed at the end by v. 2. On the left side of the page, write down the symbols for all the quantities whose values you know from the question. 3. On the right, write down the symbol for the quantity you are being asked to find. 4. Now consider what formula can relate the known quantities to the unknown one; it is likely to be one of the three formulae on the left. Write this in the middle. 5. Rearrange the formula to make the unknown the subject, and substitute in the knowns.

4.1 Forces and equilibrium

Learning objectives	Suggested teaching activities	
• Forces Part 1 • identify the forces acting in a given situation, e.g. by drawing a force diagram.	The idea of forces should already be familiar to learners, but you should discuss them with the class as much as time allows. For example, start with a brainstorm eliciting as many named forces as possible and types of situations in which they might be present, and allowing the opportunity for learners' misconceptions to be brought out and discussed. Where possible, practical activities are also helpful, reinforcing the idea that the study of Mechanics is modelling real, physical situations. For example, use an air track and slider pulled by a mass over a pulley. It is particularly helpful if you can vary the angle of elevation of the pulling force. If an air track is not available, any mass on different types of surface is equally useful, e.g. books pulled by string up a sloping desk. You can use this demonstration to bring out ideas about equilibrium and motion due to unbalanced forces, as well as normal reactions and the variable nature of frictional forces. Learners should be able to analyse situations which involve the following forces: weight, tension, friction, normal reaction, air resistance (make sure they are clear that this will often be neglected in mathematical models that involve particles) and the driving force (e.g. of an engine). Provide learners with a variety of situations or diagrams and ask them to indicate the forces and their directions.	There are a number of ways that you can do this chapter, Lami's theorem, cosine and sin rule but by far the easiest and best way to teach this chapter is simply breaking down everything into Horizontal and Vertical components.
• understand the vector nature of force, and find and use components and resultants; calculations are always required,	(The approach to this will depend on whether or not Pure Mathematics 3.7 'Vectors 'has been covered already.)	It is absolutely essential that every pupil understands how to find Horz and Vert components of forces and that they have no effect on one another at this stage.

Learning objectives	Suggested teaching activities	
not approximate solutions by scale drawing.	Divide the class into groups then set up a mass on a string passing over a pulley for each group. Learners hold this in place with a Newton meter attached to the free end of the string. They measure the size of the single force required to hold the mass stationary. Then they replace the single supporting Newton meter with two positioned at differing angles. Learners take readings from both meters and also measure the angles involved. They repeat this as many times as possible, allowing them time to investigate any connections they can find between the two forces and the original single force. Encourage learners to represent this geometrically by drawing accurate vector representations of the forces for each set of measurements. Starting with the angle between the pairs of forces as a right angle is useful, particularly for the less mathematically confident learners. Ask for feedback from each group to see what they have found and what ideas they have come up with. This should lead naturally to the idea that a single force can be replicated by two or more forces (the idea of components). Or, conversely, that two or more forces can be represented by their overall effect (the idea of a resultant). Show learners how to resolve a single force into two perpendicular components $F\cos\theta$ and $F\sin\theta$ and also how to find the resultant of two perpendicular forces. Provide plenty of these for learners to practise, either as an exercise for individual learners to do in class or independently later as this will be an essential skill throughout both Mechanics modules. Most textbooks will contain many useful examples. **(I)**	
• use the principle that, when a particle is in equilibrium, the vector	Cover both approaches here: (1) the triangle of forces and (2) finding the sum of the components of all the forces in a chosen direction.	

Learning objectives	Suggested teaching activities	
sum of the forces acting is zero, or equivalently, that the sum of the components in any direction is zero; solutions by resolving are usually expected, but equivalent methods (e.g. triangle of forces, Lami's Theorem, where suitable) are also acceptable; these other methods are not required knowledge, and will not be referred to in questions.	Learners who are less confident mathematically will probably find the second approach more accessible as the first one is likely to involve the use of the sine and cosine rules. Introduce the triangle of forces gradually, after covering the technique in three force situations where two of the forces are perpendicular, making the trigonometry more straightforward. Provide examples where the given forces are already in equilibrium and ask learners to demonstrate that they are. Also provide examples where the forces are not in equilibrium and ask learners to find the magnitude and direction of the force that is needed for equilibrium. The resource at http://tap.iop.org/mechanics/static/202/page_46254.html has good ideas for practical activities, as well as group discussion ideas and individual questions for learners.	
● Forces part 2. Forces on slopes and surfaces ● understand that a contact force between two surfaces can be represented by two components, the normal component and the frictional component.	Placing simple objects on a horizontal surface makes a good starting point for class discussion about a contact force balancing the weight of an object. Ask learners to draw a diagram showing the forces and their directions. Repeat this with the surface at different angles of elevation. Explain that the contact force can be represented by two perpendicular components, the normal reaction (ensure that the significance of 'normal' is clear) signifying a 'push' by the surface, and the frictional force resisting movement parallel to the surface.	The use of Free Body Diagrams (diagrams with all forces acting) should be drawn for all questions. Also stress the importance of writing Sum of forces Horz and Vert (or Parr and Perp) Test https://www.drfrostmaths.com/worksheets.php?wid=48318
● use the model of a 'smooth' contact, and understand the limitations of this model.	Explain the significance of the word 'smooth' in modelling situations: it indicates that you can ignore the frictional component of the contact force that resists motion parallel to the surface. Make sure that learners understand the significance of the direction of the contact force.	

Learning objectives	Suggested teaching activities	
● Forces Part 3 Friction ● understand the concepts of limiting friction and limiting equilibrium, recall the definition of coefficient of friction, and use the relationship $F = \mu R$ or $F \leq \mu R$, as appropriate; terminology such as 'about to slip' may be used to mean 'in limiting equilibrium' in questions.	Discuss why the object does not slide until a 'critical' angle is achieved. Learners investigate this, with different objects and/or different surfaces. A similar investigation includes just a horizontal surface and a measurable pulling force, to see what size force is required to move the object. www.examsolutions.net provide useful video tutorials summarising most of the ideas about friction in mechanics, for example 'What is friction, limiting equilibrium and the coefficient of friction?'	Test https://www.drfrostmaths.com/worksheets.php?wid=48323
● Connected Particles ● use Newton's third law, e.g. the force exerted by a particle on the ground is equal and opposite to the force exerted by the ground on the particle.	Give learners a variety of situations in which they identify a force. Define Newton's third law and ask for the equal and opposite force to each one that learners have identified. Some typical cases to consider (or use these after covering section 4.4 on Newton's Laws of Motion): (1) the resultant force experienced by a pulley when two connected masses are hung over it (2) a mass in a lift/elevator supported or raised by a cable (3) a 'towing' situation e.g. car and trailer/caravan **Extension activity:** Adapt case (1) above to create a problem involving strings at different angles. Good notes and a few examples and questions are at: www.mathcentre.ac.uk/resources/uploaded/mc-web-mech2-11-2009.pdf	Make sure that you spend time on Lift questions and Include Thrust questions.

4.4 Newton's laws of motion

Learning objectives	Suggested teaching activities	
• apply Newton's laws of motion to the linear motion of a particle of constant mass moving under the action of constant forces, which may include friction, tension in an extensible string and thrust in a connecting rod; if any other forces resisting motion are to be considered (e.g. air resistance) this will be indicated in the question.	It is essential that learners are able to identify the direction of motion and understand that forces resolved perpendicular to the motion must be balanced, while the resultant force parallel to the motion is what will cause the acceleration. A good description of all three of Newton's laws of motion, presented in an interesting way and with thoughtful questions in quiz form is at: www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion **Extension activity:** Interested and more able learners might find the video at: http://mathcentre.ac.uk/students/topics/mechanics/newton worth watching, although it deals with motion in two dimensions, such as orbital motion, and therefore goes beyond the scope of this scheme of work. There is good coverage of this topic at www.cimt.org.uk/projects/mepres/alevel/mechanics_ch2.pdf with useful exercises for learners, perhaps for independent study. **(I)**	

2 Fundamentals of Forces 1	Understand what forces do.	MST: p. 8-9 summarises what effects forces can have. (Note: unbalanced forces	You may like to borrow some assorted Newton meters from the Science Department, to let students get a feel for how big 1 N / 10 N / 100 N is. Explain:

(Note: you could arguably start the course with kinematics (how things move) and then go on to dynamics (what makes things move). But forces make a more interesting and tangible starting point than motion.)	Be familiar with Newton's first law. Be familiar with Newton's second law.	always cause **changes** in motion. The 'natural' state of matter, when not interfered with, is motion with constant velocity.) NP pp. 135-6 – **excellent** summary of common misconceptions about forces. Well worth going over with students. MEI1: p. 85, questions at top – on forces and their effects. MEI1: p. 86 'For Discussion' questions – on equilibrium.	- *equilibrium* - an object is in equilibrium when all the forces on it are balanced (cancel out), in other words, there is no net/resultant force on the object. - *Newton*'s *First Law* (not explicitly mentioned in the syllabus, but necessary for identifying forces and their effects) – an object's motion stays the same unless an unbalanced force acts on it (i.e. the object has constant velocity – which can mean zero velocity – unless acted on by a resultant force) - *Newton's Second Law* – an unbalanced force will cause a body to **accelerate**. (Will go on to F = ma in more detail later.)
3 Fundamentals of Forces 2	Identify different types of force. Be able to solve simple problems involving tension and pulleys.	MST: pp. 17-20 gives a clear explanation of the different types of contact force, including tension and air resistance. MEI1: pp. 90-93 – good tension explanation and worked examples. p. 93 Exercise 5B, Q. 1, 2, 3, 4, 5, 6, 7, 8.	You may like to use a tree diagram like this one to illustrate the various types of force. (Note that for the AS, students do not need to know about any non-contact force except gravity.) Explain: - weight – the gravitational force on an body towards the centre of the Earth (or whatever planet/moon it is on). Often confused with mass, which is not a force but expresses how much matter is in an object. Your mass is the same whatever planet you are on, whereas your weight may change. On Earth, W = mg, where g = gravitational field strength (10 N/kg for the purposes of the Maths AS). - tension- force transmitted along a lightweight inextensible object such as a rope. Tension can be difficult for students to understand. Make sure they know that tension acts inwards from both ends of the object (string or whatever).

		MST: p. 23, Exercise 2.4, Q. 1-3 and MEI1: p. 100, Q. 1, 2, 3 - marking the forces on diagrams. You may like to come back to this again next lesson, to pick out the third law force pairs. MST: p. 196, pulley systems explanation.	- inextensible – used of a string which does not stretch, and therefore transfers forces unaltered along its length. - contact force –force acting between two objects which are touching. A contact force between two surfaces can be represented by two components, the normal component and the frictional component. - normal (reaction) force - A normal force, FN, is a force that keeps one solid object from passing through another. 'Normal' is simply a fancy word for 'perpendicular', meaning that the force is perpendicular to the surface of contact. Intuitively, it seems the normal force magically adjusts itself to provide whatever force is needed to keep the objects from occupying the same space. If your muscles press your hands together gently, there is a gentle normal force. Press harder, and the normal force gets stronger. How does the normal force know how strong to be? The answer is that the harder you jam your hands together, the more compressed your flesh becomes. Your flesh is acting like a spring: more force is required to compress it more. The same is true when you push on a wall. The wall flexes imperceptibly in proportion to your force on it. If you exerted enough force, would it be possible for two objects to pass through each other? No, typically the result is simply to strain the objects so much that one of them breaks. - smooth pulley – a pulley without friction, which allows a string to slide through it. This allows the tension force to be transmitted along the string, unaffected by turning corners around the pulley.

4.3 Momentum

Learning objectives	Suggested teaching activities	
• use the definition of linear momentum and show understanding of its vector nature; for motion in one dimension only.	Introduce learners to the concept of linear momentum (**p**) as the product of the mass (m) and the velocity (**v**) of a particle. Emphasise that momentum is a vector quantity that acts in the direction of motion of the particle. Examples to illustrate this idea are kicking a football straight on (direct kick) and flicking a marble from behind; in both of these cases the particle moves in a straight line. When learners are secure with the definition of linear momentum, ask questions to test their understanding of the concept **(I)(F)** • If the velocity of a particle is doubled, what can we say about its momentum? • If the two particles with mass 2m and m have equal velocities, what can we say about their momenta? • If particle A has mass m and velocity **v** and particle B has mass 2m and velocity 2**v**, what can we say about their momenta? • If particle A has mass m, particle B has mass 2m and the two particles have equal momenta, what can we say about the velocities?	
• use conservation of linear momentum to solve problems that may be modelled as the direct impact of two bodies; including direct impact of two bodies where the bodies coalesce on impact; knowledge of impulse and the coefficient of restitution is not required.	As part of a flipped learning task ask learners to research conservation of linear momentum. Websites which may be helpful to learners doing this are www.khanacademy.org and www.s-cool.co.uk. Emphasise to learners that they do not need to look at examples in two dimensions. **(I)** If you prefer to introduce conservation of linear momentum as a whole class activity then these resources are also useful.	

Learning objectives	Suggested teaching activities	
	To find the resources at www.khanacademy.org, search for 'Introduction to momentum' to find 'Introduction to momentum (video)', and 'What are momentum and impulse (article)', then search for 'conservation of momentum', to find 'What is conservation of momentum? (article)', 'Bouncing fruit collision (video)' and 'Momentum: ice skater throws ball (video)'. **(I)** From www.s-cool.co.uk learners should search for 'Principle of the Conservation of Momentum' and look for the page with that title. **(I)** Other useful video resources for introducing conservation of linear momentum are at: www.tes.com/resources/search. Search for 'Conservation of linear momentum' and look for the videos by M4thsVideos. The video 'Conservation of linear momentum (COLM)' demonstrates conservation of linear momentum and looks at example questions. **(I)** The Centre for Innovation in Mathematics Teaching (CIMT) has a pdf chapter available which explains conservation of linear momentum, gives examples including one where the bodies coalesce and has a section of questions for practice: www.cimt.org.uk/projects/mepres/alevel/mechanics_ch2.pdf. The relevant section is 2.8 (pages 44-47 as labelled in the document). **(I)** Many textbooks will also have suitable questions on this topic. **(I)**	

4.5 Energy, work and power

Learning objectives	Suggested teaching activities	
• understand the concept of the work done by a force, and calculate the work done by a constant force when its point of application undergoes a displacement not necessarily parallel to the force; $W = Fd\cos\theta$; use of the scalar product is not required.	www.examsolutions.net provide useful video tutorials including: • a definition of work done by a force and a tutorial on how to use this definition to solve problems when the motion is horizontal • the same as above but for vertical motion; this also gives an introduction to gravitational potential energy • motion on an inclined plane.	Pupils need to understand the differ difference and when SUVAT can be used. The idea of non-constant acceleration and curved paths
• understand the concepts of gravitational potential energy and kinetic energy, and use appropriate formulae.	www.examsolutions.net provide useful video tutorials including: • a tutorial that defines gravitational potential energy and demonstrates how to calculate it • the same as above but for kinetic energy; tt also includes a derivation of change in kinetic energy from work done by a force.	Pupils need understand that Weight is not calculated as part of resultant Force as it is calculated in Potential Energy
• understand and use the relationship between the change in energy of a system and the work done by the external forces, and use in appropriate cases the principle of conservation of energy; including cases where the motion may not be linear (e.g. a child on a smooth curved 'slide'), where only overall energy changes need to be considered.	Make sure that learners are clear about which forces are treated as 'external' in each situation. A common error is to include the weight twice, first in calculating work done as 'weight x distance' and again as a change in potential energy. A complete treatment of the theory involved, with worked examples as well as questions for learners to try is at: www.cimt.org.uk/projects/mepres/alevel/mechanics_ch6.pdf **(I)** The video tutorial 'Conservation of energy / work energy principle' at: www.examsolutions.net/tutorials/conservation-of-energy-work-energy-principle is useful.	The "Work Energy Principal" is very important as it comes up a lot in exams.
• use the definition of power as the rate at which a force does work, and use the relationship between power, force and velocity for a force acting in the	A good explanation of the concept of power and the mathematical implications of the definition, as well as worked examples and questions for learners is at: www.cimt.org.uk/projects/mepres/alevel/mechanics_ch6.pdf **(I)** Encourage learners to think about ideas such as the maximum velocity for a given power with a given resistance. They need to be able to use the definition of power in the context of analysing forces. Make sure that learners	

Learning objectives	Suggested teaching activities	
direction of motion; including calculation of (average) power as $\frac{\text{work done}}{\text{time taken}}$; *P* = *Fv*	are clear that the power relates to the **driving** force, not to any of the other ‘external’ forces involved.	
• solve problems involving, for example, the instantaneous acceleration of a car moving on a hill against a resistance.	A good, clear force diagram is very important for these problems. Encourage learners to label the driving force as *P*/*v* wherever appropriate. You will find many useful tutorials at www.examsolutions.net including a video that defines the concept of power, develops its link with force and velocity, and works through an example of a vehicle on an inclined plane, and one that develops this to also consider acceleration.	

28, 29 Energy, Work and Power 1 and 2 (2 lessons)	Understand the concepts of gravitational potential energy and kinetic energy, and use appropriate formulae. Understand the concept of work done by a force, and know that doing work means transferring energy. Understand and use the relationship between the change in energy	MST: pp. 243-4, ‘Work Done’ – explanation. p. 245, Example 1. p. 247, Exercise 10.1, Q. 1, 2, 3, 4, 5, 6, 7, 8. p. 249, Q. 1, 3. MST: pp. 250-253, ‘Energy’ (GPE and KE) notes and examples. p. 254, Exercise 10.2, Q. 1, 2, 3, 4, 5, 7, 8, 9. p. 255, Q. 1, 2, 3, 4, 5, 6, 7, 8 – GPE and KE. MST: pp. 256-260, ‘Conservation of Energy’ notes and examples. p. 261, Exercise 10.3, Q. 1, 2, 3, 4, 5, 6. p. 262, Q. 1, 2, 4 – conservation of energy.	Students need to learn the following formulae: $KE = \frac{1}{2} mv^2$ $GPE = mgh$

	of a system and the work done by the external forces and use in appropriate cases the principle of conservation of energy.	MEI2: pp. 72-77, Mechanical Energy and its Conservation, explanation and examples. p. 78, Exercise 4A, Q. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 – work and kinetic energy. p. 86, Exercise 4B, Q. 1, 2, 3, 4, 11 – gravitational potential energy.	
30, 31 Energy, Work and Power 3 and 4 (2 lessons)	Calculate the work done by a constant force when its point of application undergoes a displacement not necessarily parallel to the force.	MST: pp. 244 – Work done and inclined forces notes. p. 246, Example 3. p. 247, Exercise 10.1, Q. 10, 11, 12, 13. p. 249, Q. 2. MEI2: p. 86, Exercise 4B, Q. 5, 6, 7, 8 – work and inclined forces.	The key thing here is for students to understand that work done is not simply force × distance moved, but force × distance moved <u>in the direction of the force</u>. (In fact, there are two ways to solve one of these problems: either multiply the force by the component of displacement in the direction of the force; or multiply the displacement by the component of force in the direction of the displacement. Either way, it ends up as (magnitude of force) × (magnitude of displacement) × cos (angle between force and displacement).

Term 2B

32 Energy, Work and Power 5	Use the definition of power as the rate at which a force does work, and use the relationship between power, force and velocity for a force acting in the direction of motion.	MST: pp. 263-5, 'Power' notes and examples. (Not Example 3 – exam questions never involve solving quadratics.) p. 267, Exercise 10.4, Q. 1, 2, 3, 4, 5, 6, 7, 8. p. 268, Q. 1, 2, 3, 4, 5 – power in 1 and 2 dimensions.	Students need to know the following formula: $P = Fv$ for moving vehicles, where F is the driving force and v is the speed.

	Solve problems involving, for example, the instantaneous acceleration of a car moving on a hill with resistance.	MEI2: pp. 90-2, 'Power' notes and examples. p. 92, Exercise 4C, Q. 1, 2, 4, 5, 6, 7, 8, 9 – power in 1 and 2 dimensions.	

33 Energy, Work and Power 6	Be able to solve exam-style questions on this topic.		Exam questions: - June 2003, Q. 1 - November 2003, Q. 1, 3 - June 2004, Q. 4, 6 - November 2004, Q. 3, 4 - June 2005, Q. 1, 7 - November 2005, Q. 2, 7 - June 2006, Q. 1, 6 - November 2006, Q. 1, 3 - June 2007, Q. 3, 5
34 Calculus in Kinematics 1	Know the relationships between displacement, velocity and acceleration in terms of calculus methods. Be able to use differentiation to find velocity and acceleration.	MST: pp. 477-8, 'Using Differentiation to find Velocity and Acceleration' notes and example. (Example 1 only.) p. 480, Exercise 18.1, Technique Q. 1a), 3, 4. MEI1, p. 32, Exercise 2E, Q. 1, 2, 7 – differentiating to find acceleration.	By this stage, calculus should have been covered in Pure Mathematics. For Mechanics, students need to be able to integrate and differentiate, but the problems are restricted to calculus used in unit P1, and only involve straightforward polynomials – not trigonometric functions or square roots. Calculus is used when problems involve variable acceleration; for constant acceleration, the usual formulae can be applied. There are not many useable questions in the textbooks, as most of the questions use calculus which is beyond the level of the Mechanics exam. You may need to use exam questions here.
35 Calculus in Kinematics 2	Be able to use integration to find velocity and displacement.	MST: pp. 481-482, 'Using Integration to find Velocity and Displacement' notes and example. p. 484, Exercise 8.2, Technique Q. 1, Contextual Q. 1. MEI1, p. 32, Exercise 2E, Q. 3, 6 – integrating to find v and s.	
36, 37 Calculus in Kinematics 3	Be able to answer exam-style questions on this topic.		Exam questions: - June 2003, Q. 4 - November 2003, Q. 7

and 4 (2 lessons)			- June 2004, Q. 5 - November 2004, 7 - June 2005, Q. 5 - November 2005, Q. 6 - June 2006, Q. 2 - November 2006, Q. 4 - June 2007, Q. 6
38, 39, 40 Consolidation and Exam Practice			More practice on exam questions, with time limits.