

Scheme of Work

Cambridge
International
AS & A Level

Cambridge International AS & A Level Mathematics

9709/04 Mechanics 1 (M1)

For examination from 2017



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Introduction

This scheme of work provides ideas about how to construct and deliver a course. It has been broken down into different units of the three subject areas of Pure Mathematics (units P1, P2 and P3), Mechanics (units M1 and M2) and Probability & Statistics (units S1 and S2). For each unit there are suggested teaching activities and learning resources to use in the classroom for all of the syllabus learning objectives.

This scheme of work, like any other, is meant to be a guideline, offering advice, tips and ideas. It can never be complete but hopefully provides teachers with a basis to plan their lessons. It covers the minimum required for the Cambridge International AS & A Level course but also adds enhancement and development ideas. It does not take into account that different schools take different amounts of time to cover the Cambridge International AS & A Level course.

The mathematical content of Mechanics 1 in the syllabus is detailed in the tables below. The order in which topics are listed is not intended to imply anything about the order in which they might be taught.

Recommended prior knowledge

Knowledge of the content of Cambridge O Level / Cambridge IGCSE® Mathematics is assumed.

Candidates will be expected to be familiar with scientific notation for the expression of compound units, e.g. 5 m s^{-1} for 5 metres per second.

As well as demonstrating skill in the appropriate techniques, candidates will be expected to apply their knowledge in the solution of problems. Individual questions set may involve ideas and methods from more than one section of the relevant content list.

Outline

Suggestions for independent study (**I**) and formative assessment (**F**) are indicated, where appropriate, within this scheme of work. The activities in the scheme of work are only suggestions and there are many other useful activities to be found in the materials referred to in the learning resource list.

Opportunities for differentiation are indicated as **basic/consolidation** and **challenging/extension**. There is the potential for differentiation by resource, length, grouping, expected level of outcome, and degree of support by the teacher, throughout the scheme of work. Timings for activities and feedback are left to the judgment of the teacher, according to the level of the learners and size of the class. Length of time allocated to a task is another possible area for differentiation.

Teacher support

Teacher Support (<http://teachers.cie.org.uk>) is a secure online resource bank and community forum for Cambridge teachers, where you can download specimen and past question papers, mark schemes and other resources. We also offer online and face-to-face training; details of forthcoming training opportunities are posted online.

This scheme of work is available as PDF and an editable version in Microsoft Word format; both are available on Teacher Support at <http://teachers.cie.org.uk>. If you are unable to use Microsoft Word you can download Open Office free of charge from www.openoffice.org.

Resources

The up-to-date resource list for this syllabus, including textbooks endorsed by Cambridge, is listed at www.cie.org.uk

Endorsed textbooks have been written to be closely aligned to the syllabus they support, and have been through a detailed quality assurance process. As such, all textbooks endorsed by Cambridge for this syllabus are the ideal resource to be used alongside this scheme of work as they cover each learning objective.

Websites and videos

This scheme of work includes website links providing direct access to internet resources. Cambridge International Examinations is not responsible for the accuracy or content of information contained in these sites. The inclusion of a link to an external website should not be understood to be an endorsement of that website or the site's owners (or their products/services).

The website pages referenced in this scheme of work were selected when the scheme of work was produced. Other aspects of the sites were not checked and only the particular resources are recommended.

1. Forces and equilibrium

Learning objectives	Suggested teaching activities
Identify the forces acting in a given situation.	<p>The idea of forces should already be familiar to learners, but it is a good idea for you to discuss them with the class as much as time allows. You could perhaps 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 confronted.</p> <p>Where possible, practical activities are also helpful, reinforcing the idea that the study of Mechanics is modelling real, physical situations. You could 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.</p> <p>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).</p> <p>You could provide learners with a variety of situations or diagrams and ask them to indicate the forces and their directions.</p>
Understand the vector nature of force, and find and use components and resultants.	<p>(The approach to this will depend on whether or not the vector section of unit P1 has been covered already.)</p> <p>Divide the class into groups then set up a mass on a string passing over a pulley for each group. Learners should hold this in place with a Newton meter attached to the free end of the string. They should measure the size of the single force required to hold the mass stationary. Then they can replace the single supporting Newton meter with two positioned at differing angles. Learners should take readings from both meters and should also measure the angles involved. This should be repeated as many times as possible, allowing learners time to investigate any connections they can find between the two forces and the original single force.</p> <p>You could encourage learners to represent this geometrically by drawing accurate vector representations of the forces for each set of measurements. It might prove useful, particularly for the less mathematically confident learners, if the angle between the pairs of forces is initially a right angle.</p>

Learning objectives	Suggested teaching activities
	<p>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).</p> <p>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.</p> <p>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)</p> <p>Past papers: (I)(F) June 2013 paper 41 question 3 November 2012 paper 41 question 4 November 2012 paper 42 question 4 November 2014 paper 42 question 2</p>
<p>Use the principle that, when a particle is in equilibrium, the vector sum of the forces acting is zero or, equivalently, that the sum of the components in any direction is zero.</p>	<p>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. 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. It is a good idea to 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.</p> <p>This resource 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.</p> <p>Past papers: (I)(F) June 2012 paper 42 question 2</p>
<p>Understand that a contact force between two surfaces can be represented by two components, the normal component and the frictional component.</p>	<p>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,</p>

Learning objectives	Suggested teaching activities
	and the frictional force resisting movement parallel to the surface.
Use the model of a 'smooth' contact, and understand the limitations of this model.	<p>Explain the significance of the word 'smooth' in modelling situations, indicating that you can ignore the frictional component of the contact force that resists motion parallel to the surface. Ensure that learners understand the significance of the direction of the contact force.</p> <p>Past papers: (I)(F) June 2013 paper 42 question 7 (This question involves motion of an object on a smooth surface, although skills from other parts of the Scheme of Work are also needed) November 2014 paper 41 question 2 November 2014 paper 42 question 4 (This question models the same situation twice; once on a smooth surface and once on a rough surface, and is useful to demonstrate the difference between the two cases)</p>
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.	<p>Discuss why the object does not slide until a 'critical' angle is achieved. This could form the basis of an investigation, with different objects and/or different surfaces. A similar investigation might include just a horizontal surface and a measurable pulling force, to see what size force is required to move the object.</p> <p>This website http://www.examsolutions.net/maths-revision/mechanics/statics/friction/tutorial-1.php has a useful video tutorial summarising most of the ideas about friction in Mechanics.</p>
Use Newton's third law.	<p>Present learners with a variety of situations in which a force is to be identified. Define Newton's third law and ask for the equal and opposite force to each one that has been identified. Some typical cases to consider: (1) the resultant force experienced by a pulley when two connected masses are hung over it, (a problem involving strings at different angles could be used as an extension exercise), (2) a mass in a lift/elevator supported or raised by a cable, (3) a 'towing' situation e.g. car and trailer/caravan (these might be better used after the section on Newton's Laws of Motion has been covered).</p> <p>You can find good notes and a few examples and questions here: http://www.mathcentre.ac.uk/resources/uploaded/mc-web-mech2-11-2009.pdf</p>

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 (in one dimension only).	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. A few simple examples of this should be sufficient. You should stress that negative speed or distance is not appropriate, and that use of these will be penalised in exams. Also ensure that learners understand that a negative acceleration is equivalent to a positive deceleration.
<p>Sketch and interpret displacement-time graphs and velocity-time graphs, and in particular appreciate that:</p> <ul style="list-style-type: none"> - 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. 	<p>A summary of the key points for the two types of graphs, with a few questions, is given here: http://www.mathcentre.ac.uk/resources/uploaded/mc-web-mech1-10-2009.pdf</p> <p>A more complete discussion, with extensive examples and questions, is at http://www.cimt.plymouth.ac.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).</p> <p>Past papers: (I)(F) June 2013 paper 42 question 6 November 2013 paper 42 question 7 parts (i) and (ii) (later parts require skills from other parts of the Scheme of Work) November 2013 paper 43 question 4</p>
Use differentiation and integration with respect to time to solve simple problems concerning displacement, velocity and acceleration (restricted to calculus within the scope of unit P1).	<p>The document mentioned above (http://www.cimt.plymouth.ac.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.</p> <p>Past papers: (I)(F) June 2012 paper 41 question 4 June 2012 paper 42 question 3</p>
Use appropriate formulae for motion with constant acceleration in a straight line.	<p>The document mentioned above (http://www.cimt.plymouth.ac.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. It would be useful to challenge learners to derive the formulae, perhaps giving them a few hints. They could start from the basic definition of constant acceleration as the difference in velocities per second, or from their understanding of acceleration as the gradient of a velocity-time graph.</p>

Learning objectives	Suggested teaching activities
	<p>https://www.youtube.com/watch?v=jfOSQBB7Bhs is 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). It is particularly important to make it 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.</p> <p>Learners will benefit from attempting a wide variety of questions requiring them to use the equations of motion, and you can find many such questions in textbooks and at the links above.</p> <p>Past paper questions on this objective often appear in questions that also cover other objectives, such as the use of Newton’s 2nd law or vertical motion under gravity. This question applies only to this objective:</p> <p>Past papers: (I)(F) June 2013 paper 42 question 2</p>

3. 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.	<p>It is essential that learners can 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. https://www.khanacademy.org/science/physics/forces-newtons-laws/newtons-laws-of-motion has a good description of all three of Newton's laws of motion, presented in an interesting way and with thoughtful questions in quiz form.</p> <p>Interested and more able learners might find the video here 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.</p> <p>There is good coverage of this topic in the document mentioned above (http://www.cimt.plymouth.ac.uk/projects/mepres/alevel/mechanics_ch2.pdf) with useful exercises for learners, perhaps for independent study. (I)</p> <p>Of the past paper questions that explore this objective, many also require other objectives, for example regarding mass and weight, or motion on an inclined plane. Here are some which focus largely on horizontal motion:</p> <p>Past papers: (I)(F) June 2013 paper 42 question 1 June 2013 paper 43 question 6 November 2013 paper 41 question 4</p>
Use the relationship between mass and weight.	<p>You should ensure 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.</p> <p>http://www.cimt.plymouth.ac.uk/projects/mepres/alevel/mechanics_ch2.pdf has 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.</p> <p>Past papers: This objective is covered extensively in questions listed under the vertical motion and motion on an inclined plane objective (see later).</p>
Solve simple problems which may be modelled as the motion of a particle	<p>This short video clip shows clearly how to analyse the forces on an object moving on an inclined plane: https://www.youtube.com/watch?v=dA4BvYdw7Xg</p>

Learning objectives	Suggested teaching activities
moving vertically or on an inclined plane with constant acceleration.	<p>Past papers: (I)(F) June 2012 paper 43 question 6 June 2013 paper 41 question 3 June 2013 paper 41 question 5</p>
Solve simple problems which may be modelled as the motion of two particles, connected by a light inextensible string which may pass over a fixed smooth peg or light pulley.	<p>You will find it worthwhile to 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.</p> <p>This link provides helpful notes, examples and questions: http://www.mathcentre.ac.uk/resources/uploaded/mc-web-mech2-12-2009.pdf (I)</p> <p>A video tutorial with a clear example of how to solve vertical string questions is here: http://www.examsolutions.net/maths-revision/mechanics/dynamics/connected-particles/vertical-strings/tutorial-1.php</p> <p>This link shows an animation, with explanations, when at least one of the strings is not vertical: http://www.examsolutions.net/maths-revision/mechanics/dynamics/connected-particles/inclined-planes/animation/tutorial-1.php It also links to examples of how to solve these problems.</p> <p>Past papers: (I)(F) June 2012 paper 41 question 6 June 2012 paper 43 question 7 June 2013 paper 43 question 7</p>

4. 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 (use of the scalar product is not required).	<p>This link gives 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: http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/work/horizontal/tutorial-1.php and, for vertical motion, here http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/work/vertical/tutorial-1.php. This also gives an introduction to gravitational potential energy.</p> <p>This link deals with motion on an inclined plane http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/work/incline/tutorial-1.php</p> <p>Past papers: (I)(F) June 2012 paper 42 question 1 June 2012 paper 43 question 1 November 2012 paper 42 question 1</p>
Understand the concepts of gravitational potential energy and kinetic energy, and use appropriate formulae.	<p>http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/gravitational-potential-energy/tutorial-1.php has a video tutorial which defines gravitational potential energy and demonstrates how to calculate it, and http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/kinetic-energy/tutorial-1.php does the same for kinetic energy. It also includes a derivation of change in kinetic energy from work done by a force.</p> <p>Past papers: (I)(F) June 2012 paper 41 question 3 parts (i) and (ii) November 2014 paper 42 question 5 part (i)</p>
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.	<p>It is a good idea to 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.</p> <p>This link has a complete treatment of the theory involved here, with worked examples as well as questions for learners to try http://www.cimt.plymouth.ac.uk/projects/mepres/alevel/mechanics_ch6.pdf (I)</p> <p>There are video tutorials here http://www.examsolutions.net/maths-revision/syllabuses/Index/period-1/Mechanics/module.php#GPE. Click on the link to 'Conservation of energy / Work-Energy Principle'.</p>

Learning objectives	Suggested teaching activities
	<p>Past papers: (I)(F) June 2012 paper 43 question 5 June 2013 paper 41 question 2 June 2013 paper 42 question 2</p>
<p>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.</p>	<p>http://www.cimt.plymouth.ac.uk/projects/mepres/alevel/mechanics_ch6.pdf has a good explanation of the concept of power and the mathematical implications of the definition. There are worked examples and questions for learners. (I)</p> <p>It is important to 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. Ensure that learners are clear that the power relates to the driving force, not to any of the other 'external' forces involved.</p> <p>Past papers: (I)(F) June 2012 paper 41 question 3 June 2012 paper 42 question 6 June 2013 paper 41 question 4</p>
<p>Solve problems involving, for example, the instantaneous acceleration of a car moving on a hill with resistance.</p>	<p>A good, clear force diagram is very important for these problems. Encourage learners to label the driving force as P/v wherever appropriate.</p> <p>http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/power/uniform-motion/tutorial-1.php is a video tutorial 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. http://www.examsolutions.net/maths-revision/mechanics/work-energy-power/power/acceleration/tutorial-1.php develops the previous tutorial to consider acceleration as well.</p> <p>Past papers: (I)(F) June 2012 paper 41 question 1 June 2012 paper 43 question 4 June 2013 paper 42 question 5</p>

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