THE ACADEMY OF ST NICHOLAS	Y12 Applied	CH09 7.1, 7.2, 7.3, 8.3	Mechanics – Constant Acceleration	Lessons 5

<table>
<tr><th>Essential Knowledge Milestones</th><th>Teaching Points</th></tr>
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- Understand and interpret displacement-time graphs
- Understand and interpret velocity-time graphs
- Derive the constant acceleration formulae and use them to solve problems
- Use the constant acceleration formulae to solve problems involving vertical motion under gravity

Success Criteria

- ❑ Know that velocity is the rate of change of displacement and that on a displacement-time graph the gradient represents the velocity.
- ❑ Know that acceleration is the rate of change of velocity and that in a velocity-time graph the gradient represents the acceleration.
- ❑ Know that the area between a velocity-time graph and the horizontal axis represents the distance travelled.
- ❑ Know the standard set of letter used for the motion of an object moving in a straight line with constant acceleration.
- ❑ Know how to derive all 5 of the constant acceleration formulae through graphical methods and manipulation of formulae.
- ❑ Know how to use the 5 kinematics formulae to solve problems (although there is no need to remember them FORMULA BOOK)
- ❑ Know that the force of gravity causes all objects to accelerate towards the earth. If you ignore the effects of air resistance, this acceleration is constant and can be modelled as a particle with $g = 9.8$ ms^{-1}

Assumed Prior Knowledge/ Links / Interleaving

GCSE (9-1) in Mathematics at Higher Tier

- **R1** Change freely between related standard units (e.g. time, length, area, volume/capacity, mass) and compound units (e.g. speed, rates of pay, prices, density, pressure) in numerical and algebraic contexts
- **R11** Use compound units such as speed, rates of pay, unit pricing, density and pressure
- **A2** Substitute numerical values into formulae and expressions, including scientific formulae
- **A5** Understand and use standard mathematical formulae; rearrange formulae to change the subject
- **A14** Plot and interpret graphs (including reciprocal graphs and exponential graphs) and graphs of non-standard functions in real contexts to find approximate solutions to problems such as simple kinematic problems involving distance, speed and acceleration
- **A15** Calculate or estimate gradients of graphs and area under graphs (including quadratic and non-linear graphs), and interpret results in cases such as distance-time graphs, velocity-time graphs and graphs in financial contexts

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- Introduce this topic by making links to the GCSE (9-1) in Mathematics prior knowledge for distance–time (travel) and speed–time graphs. Kinematics is the analysis of a particle's motion without reference to the resultant force that caused that motion.
- Stress that forces causing the motion of the body in this section are *constant*, therefore acceleration is constant and this results in a *straight line* travel speed-time or velocity-time graph.
- Extend the ideas to displacement by considering a particle which moves in reverse direction back beyond the starting point.
- For a velocity–time graph, consider the units for the area of a unit square 1 m s^{-1} by 1 s. The 's' cancels, leaving 'm', therefore the area represents the displacement.
- Discuss and interpret graphs that model real situations. For example, the distance–time graph for a particle moving with constant speed, the velocity–time graph for a particle with constant acceleration.
- Using the moving man program is really important here to show that the journey can be modelled as 3 different graphs representing the displacement, velocity and acceleration. What is useful is to be able visualise what certain graphical features mean. Ie. What does it mean when the displacement graph crosses the x axis? What does the velocity graph mean at that time?
- After modelling lots of journeys and having these discussions it is well worth doing the matching graph activity.
- Contrast the previous graphical approach with this algebraic approach. Note that there are five quantities, *s, u, v, a* and *t* (four vectors and one scalar) and each formula relates four of them hence there are five formulae. The formulae that must be derived and learnt are:
    - $v = u + at$
    - $s = \frac{(u+v)t}{2}$
    - $s = ut + \frac{1}{2}at^2$
    - $v^2 = u^2 + 2as$
    - $s = vt - \frac{1}{2}at^2$
- These formulae are only valid for *constant* acceleration in a straight line (and are referred to as the *suvat* formulae).
- Students must learn how to derive the first two from graphical methods. The remaining three must be derived from algebraic methods using variable elimination.
- When solving problems, write down known variables and the variable(s) to be found – this should help to identify which one (or more, as some problems will involve simultaneous equations) of the *suvat* formulae to select. Emphasise to students the need to make sure units are compatible.

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• **A17** Solve linear equations in one unknown algebraically (including those with the unknown on both sides of the equation) • **A18** Solve quadratic equations (including those that require rearrangement) algebraically by factorising, by completing the square and by using the quadratic formula AS Mathematics – Pure Mathematics content • **3.1** Gradient (See Unit 2a of the SoW)	• Model the good practice of drawing a diagram to illustrate the situation whenever possible, especially when considering vertical motion under gravity. This will encourage students to draw their own diagrams. • Mark the positive direction on the diagram and take acceleration due to gravity (g) to be 9.8 m s^{-2} unless directed otherwise. Students may assume that g is constant, but they should be aware that g is not a universal constant but depends on location. • If an object is thrown upwards and upwards is taken as being positive then a = –9.8 m s^{-2}. Explain that the velocity is zero at the greatest height and there is symmetry in the path (up and down to the same point) due to the fact that we model air resistance as being negligible. • Students will need encouraging to 'trust in vectors'. They won't be convinced that if something is thrown upwards then lands 5 metres below you that you can just write s = -5. They will want to split the journey in to 2 parts! • Some suvat equations will results in a quadratic to solve. Again, discuss in what scenarios this would make sense. Again model out the journey using the moving man.
Potential Barriers to Access /Misconceptions	**Opportunities for Reasoning/Problem Solving/Proofs**
• Many students can draw a velocity time graph with the correct shape, but do not always label the required speeds and times clearly on the axes. Students often tend to add a scale (for example 4, 8, 12, 16, …) unnecessarily, rather than just indicating the initial and final speeds. • Students will confuse the different graphs and will have misconceptions around various shapes. Use the moving man frequently and get the students to try it too. • Candidates are able to find distance travelled and the acceleration from velocity–time graphs and can find an average speed, but some struggle with the vocabulary of velocity and displacement. • Students are generally able to use *suvat* formulae in 2D to find unknown heights, velocities etc. However, students sometimes ignore the significance of a negative value for velocity, acceleration or displacement and don't refer their answer back to the original problem. They need to recognise that s = **–**3 m means the object is 3 m *below* its starting point in the negative direction i.e. s is effectively a coordinate. This is where a diagram helps students understand the physics of the situation.	• Throw an object straight (vertically) up in the air. Time the flight and estimate the greatest height, to scale the graphs correctly, and keep for possible later use. Draw the displacement–time and velocity–time graphs (upward direction positive and initial velocity non-zero). If the object is caught at the same height at which it was thrown, what is the average velocity for the motion? • One of the more demanding problems is when two objects are released (or dropped) at different times, say 2 seconds apart, and students are asked to find the common position when one catches-up or passes the other. Students may find it difficult to select the times (values of t) to assign in the equations; they may need guiding towards t and (t – 2) or t and (t + 2). • Sit students in teams with the moving man program and encourage them to complete the matching graphs problem. Ask probing questions throughout to really gauge their understanding. • The traffic applet allows students to visualise a journey and associated graphs. • Don't forget to revisit the rock down a hole video from the previous chapter.

Key Mathematical Vocabulary	Distance (m), displacement (m), speed (m s^{-1}), velocity (m s^{-1}), acceleration (m s^{-2}), retardation (m s^{-2}), deceleration (m s^{-2}), scalar, vector, 2D, linear, area, trapezium, gradient, equations of motion, gravity, constant, 9.8 m s^{-2}, vertical.

Personal Development	Notes	Resources
Pupils are taught that they must 'respect' each other's opinions and well-being when working collectively in class. Pupils to learn that mathematicians have 'ambition' to push boundaries when aiming to solve new problems **Resilience** – never giving up! Building confidence across the problem solving aspects of the course. **Ambition** – living life to the full – fulfilling dreams and aspirations – linking to future career and ambition plans. **Respect** – respect for others – the 9 protected characteristics	• The guidance on the specification document states that graphical solutions to problems may be required. This section assumes *constant* acceleration; hence the graphical approach involves linear line segments and the familiar equations of linear motion *suvat*, formulae for constant acceleration. (N.B. 'equation of motion' refers to $F = ma$, and is nothing to do with these formulae).	• Motion graphs matching activity • Moving man applet • Traffic applet • Guy throw's rock down big hole video!

Personal Best – First Work – Best Work every time	• The guidance also states that derivation of constant acceleration formulae may use knowledge of sections 7.2 and/or 7.4 (Unit 9). • Kinematics 2 (Unit 9) analyses particles' motion under a <u>variable</u> force, hence a variable acceleration. The mathematical model for this requires calculus which is covered in AS Mathematics – Pure Mathematics content, see SoW Units 6 and 7. • The usual value for *g* in this course is 9.8 m s^{-2}, but some questions may specify a different value. Students may assume that *g* is constant, but should be aware that it is not a universal constant but depends on location.	