	Y12 Applied	CH08 6.1	Mechanics – Modelling in Mechanics	Lessons 4

Essential Knowledge Milestones

- Understand how the concept of a mathematical model applies to mechanics
- Understand and be able to apply some of the common assumptions used in mechanical models
- Know SI units for quantities and derived quantities used in mechanics
- Know the difference between scalar and vector quantities

Success Criteria

- ❑ Know that mathematical models can be created to simulate real life situations but it is often necessary to simplify the problem by making assumptions.
- ❑ You can comment on the validity of a prediction from a model and are aware that modelling assumptions can affect the validity.
- ❑ You know all common models and their modelling assumptions
- ❑ You know all SI units, their derived compound units and how to convert non SI units into SI units
- ❑ You can correctly label force diagrams
- ❑ You understand that scalar quantities are always positive. When considering motion in a straight line, vector quantities can be positive or negative
- ❑ You can describe vectors using **i, j** notation, where **i** and **j** are the unit vectors in the positive *x* and *y* directions

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
- **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

There may not be a direct examination question on this topic. However, the modelling process and fluent knowledge of the S.I. units is a vital pre-requisite that underpins the rest of the mechanics course.

Teaching Points

- Begin by asking students 'What is mechanics?' Lead them to the idea that mechanics is a branch of applied mathematics that deals with motion and the forces producing motion.
- Students need to be comfortable with the idea that mathematics is used to model real life and need to become familiar with the modelling cycle:

mechanics problem → create a mathematical model (using diagrams, general principles or formulae) → solve the model → refer back to the original problem → refine the model

- [Link with the data-handling cycle]
- It is important for students to get a 'feel' for mechanics at this early stage in order to support later work.
- Revise GCSE (9-1) in Mathematics compound units for speed and acceleration and make sure that students are comfortable converting from one unit to another, e.g. from km h^{-1} into m s^{-1}. Context for this is important. Students should know that all calculation should take place with SI units hence they need to be comfortable with this. It will need practice! Also, don't forget tonnes to kg conversions ☺
- Define the vector quantities displacement and velocity as the vector versions of distance and speed respectively.
- Begin by walking across the room and explaining the difference between position (referred to a fixed origin), displacement (a vector measured from any position) and distance (a scalar quantity for the total movement). Then move onto discussing speed (the rate at which an object covers distance) and velocity (the rate of change of displacement or speed in a certain direction. The moving man applet is also excellent for this and should be used heavily over the course of the next few lessons.
- Mention the special acceleration (for a falling object) due to gravity. In this course, this value is assumed to be a constant *g*, usually 9.8 m s^{-2} though it does vary in the real world. It's important to point this out to Physicists who are told to use 9.81 m s^{-2}
- This could be a good opportunity to dispel common misconceptions around weight and mass. Make it clear that mass is the amount of 'stuff' something is made of, is a scalar and is fixed (in kg), whereas weight is a force of attraction between an object and the centre of the earth and can vary depending on gravity and is measured in newtons. Hence weight = mass × gravity (or $W = mg$).
- Students need a strong understanding of quadratics as many models use this format for their trajectory. Calculator skills are important for efficient solving.
- Although modelling assumptions are slightly boring they are important and carry lots of marks! They must learn the model and their assumptions.
- Guide them into it by watching the 'Guy throws rock down deep hole' video. I tell the students that we will find how deep the whole is after the next few lessons but what assumptions could we make now.

Potential Barriers to Access /Misconceptions	Opportunities for Reasoning/Problem Solving/Proofs
• Students can generally correctly state assumptions, but they need to make sure that any assumptions or statements about the model relate directly to the context they are considering. For example they could make the comment 'the resistance will not be constant' more specific by saying 'resistance will increase as velocity increases'. • As mentioned above, students may mix up mass and weight and their related units. Some struggle to use the correct vocabulary e.g. for velocity and displacement. It is important to be really clear when giving the definitions and to always use the correct vocabulary in discussions.	Examples of problems that may be solved in this way include: • How far apart should the cameras be within an average speed zone? • At what angle should you hold an umbrella to keep snow off you? Some examples of simplifying assumptions for these problems include: • treating the car as a particle • motion is in a straight line • snow falls vertically. Show some basic force diagrams (as an introduction to Unit 8a) to illustrate different types of forces such as weight, reaction and tension (all in newtons). • Do make sure that you come back to the 'how deep is the whole' problem when you have completed kinematics

Key Mathematical Vocabulary	Modelling, smooth, rough, light, inelastic, inextensible, particle, rigid body, mass, weight, rod, plane, lamina, length, distance (m), displacement (m), velocity (m s^{-1}), speed (m s^{-1}), acceleration (m s^{-2}), force (N), retardation (m s^{-2}), newtons (N), scalar, vector, direction, magnitude, (normal) reaction, friction, tension, thrust, compression

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 **Personal Best** – First Work – Best Work every time	• The particle (point mass) model is introduced here, i.e. the body has no size but does have mass, so rotation is ignored and the forces all act at one point. • The language of simplifying assumptions (light, smooth, uniform, inextensible, thin, rigid etc) is mostly introduced in subsequent sections. • Defining the units of acceleration as 'metres per second per second' helps explain the concept of rate of change of speed. Show that m/s/s is algebraically equivalent to ms^{-2}. It may also help to think about it in terms of 'how many metres per second of speed is the object gaining every second?'	• Moving man applet • Guy throw's rock down big hole video!