UNIT 6: Quantities and units in mechanics

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SPECIFICATION REFERENCES

6.1 Understand and use fundamental quantities and units in the S.I. system: length, time, mass. Understand and use derived quantities and units: velocity, acceleration, force, weight

PRIOR KNOWLEDGE

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

KEYWORDS

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

NOTES

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.

6a. Introduction to mathematical modelling and standard S.I units of length, time and mass (6.1)

Teaching time
1 hour

OBJECTIVES

By the end of the sub-unit, students should:

- understand the concept of a mathematical model, and be able to abstract from a real-world situation to a mathematical description (model);
- know the language used to describe simplifying assumptions;
- understand the particle model;
- be familiar with the basic terminology for mechanics;
- be familiar with commonly-made assumptions when using these models;
- be able to analyse the model appropriately, and interpret and communicate the implications of the analysis in terms of the situation being modelled;
- understand and use fundamental quantities and units in the S.I. system: length, time and mass;
- Understand that units behave in the same way as algebraic quantities, e.g. meters per second is $m/s = m \times 1/s = ms^{-1}$.

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.

OPPORTUNITIES FOR PROBLEM SOLVING/MODELLING

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.

COMMON MISCONCEPTIONS/EXAMINER REPORT QUOTES

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’.

NOTES

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.

6b. Definitions of force, velocity, speed, acceleration, weight and displacement; Vector and scalar quantities (6.1)	Teaching time 1 hour

OBJECTIVES

By the end of the sub-unit, students should:

- understand and use derived quantities and units: velocity, acceleration, force, weight;
- know the difference between position, displacement and distance;
- know the difference between velocity and speed, and between acceleration and magnitude of acceleration;
- know the difference between mass and weight (including gravity);
- understand that there are different types of forces.

TEACHING POINTS

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}.

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.

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.

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 $W = mg$).

OPPORTUNITIES FOR PROBLEM SOLVING/MODELLING

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).

COMMON MISCONCEPTIONS/EXAMINER REPORT QUOTES

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.

NOTES

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?'