

A1 : Kinematics -Form Position to Motion: SUVAT Equations

Duration: 6 Weeks, 6 hour
Unit dates: 5th Sep 2026 - 17th Oct 2026
Subjects: Physics
Levels: HL
Grades: DP 1
Owner: Utkarsh Kumar

Inquiry & action

Unit basics

Unit description and texts

In this unit, students develop a quantitative understanding of motion by beginning with a simple question: **How can we describe the position and motion of an object mathematically?**
Students progressively move from representing position using coordinates to describing one-dimensional and two-dimensional motion using mathematical functions and graphs. Through interactive simulations, Desmos-based mathematical modelling, visualisations, and guided investigations, students explore the relationships between displacement, velocity, acceleration and time. Rather than learning the SUVAT equations as isolated formulae, students derive meaning from physical situations and use the equations as models for describing motion. Students investigate uniform motion, uniformly accelerated motion and projectile motion, while developing fluency in interpreting position-time, velocity-time and acceleration-time graphs.
A key component of the unit is the introduction of **measurement uncertainty and uncertainty propagation**. Students examine how uncertainty in measured quantities affects calculated quantities and begin to distinguish between measurement uncertainty, percentage uncertainty and uncertainty in a mathematical model.
Students work increasingly independently through an inquiry-based digital laboratory environment in which they can manipulate variables, observe physical consequences, collect data, record observations, test predictions and evaluate mathematical models. AI-supported questioning is used as a Socratic tool to encourage reasoning rather than provide direct answers.
The unit therefore establishes the foundations not only for mechanics but also for **experimental design, data analysis, mathematical modelling, uncertainty evaluation and future Individual Scientific Investigations (IA).**

Final assessments for unit

A1 Kinematics Investigation Students will complete an individual quantitative investigation based on a kinematics system. Possible contexts include acceleration of a moving object, stopping distance, projectile motion, motion on an inclined plane, or free-fall.
Students are expected to:

1. formulate a focused research question,

2. identify variables,
3. develop a relevant mathematical model,
4. collect or generate quantitative data,
5. include measurement uncertainty,
6. analyse the data,
7. compare results with the mathematical model,
8. interpret deviations,
9. evaluate limitations and assumptions,
10. reach a supported conclusion.

The investigation should begin developing the habits required for future IB scientific investigation work.
Assessment Evidence

Students should be able to demonstrate:

- correct use of kinematic quantities,
- correct interpretation of motion graphs,
- appropriate selection and use of SUVAT equations,
- mathematical reasoning,
- appropriate units and significant figures,
- treatment of uncertainty,
- graphical/data analysis,
- evaluation of models,
- evidence-based conclusions,
- scientific communication.

Learning goals

Aims

Subject group aims - Sciences

- Develop conceptual understanding that allows connections to be made between different areas of the subject, and to other DP sciences subjects
- Acquire and apply a body of knowledge, methods, tools and techniques that characterize science
- Develop the ability to analyse, evaluate and synthesize scientific information and claims
- Develop the ability to approach unfamiliar situations with creativity and resilience
- Design and model solutions to local and global problems in a scientific context
- Develop technology skills in a scientific context

Objectives

- Demonstrate knowledge of skills, techniques and methodologies
- Understand and apply knowledge of terminology and concepts
- Understand and apply knowledge of skills, techniques and methodologies
- Demonstrate knowledge of terminology, facts and concepts

Syllabus

- A Space, time and motion
  - A.1 Kinematics
    - Guiding questions
      - How can the motion of a body be described quantitatively and qualitatively?
      - How can the position of a body in space and time be predicted?
      - How can the analysis of motion in one and two dimensions be used to solve real-life problems?
    - Understandings - SL and HL
      - Students should understand the equations of motion for solving problems with uniformly accelerated motion as given by
        - s = (u + v)/2 *t
        - v = u + at
        - s = ut + 1 /2 *at2
        - v 2 = u 2 + 2as

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- Students should understand
  - that the motion of bodies through space and time can be described and analysed in terms of position, velocity, and acceleration
  - velocity is the rate of change of position, and acceleration is the rate of change of velocity
  - the change in position is the displacement
  - the difference between distance and displacement
  - the difference between instantaneous and average values of velocity, speed and acceleration, and how to determine them
  - motion with uniform and non-uniform acceleration
  - the behaviour of projectiles in the absence of fluid resistance, and the application of the equations of motion resolved into vertical and horizontal components
  - the qualitative effect of fluid resistance on projectiles, including time of flight, trajectory, velocity, acceleration, range and terminal speed
- Linking questions
  - How does the motion of a mass in a gravitational field compare to the motion of a charged particle in an electric field?
  - How are the equations for rotational motion related to those for linear motion?
  - When can certain types of problems on projectile motion be solved by applying conservation of energy instead of kinematic equations?
  - How effectively do the equations of motion model Newton's laws of dynamics?
  - How does a gravitational force allow for orbital motion?
  - How does the motion of an object change within a gravitational field?
  - How does graphical analysis allow for the determination of other physical quantities? (NOS)

Learner Profile

- Inquirers
- Thinkers
- Knowledgeable
- Communicators
- Reflective
- Principled
- Open-minded

Inquiry: Establishing the purpose of the unit

Transfer goals

- Students will be able to apply mathematical modeling and data analysis skills to understand and predict motion in various real-world contexts, even those beyond basic kinematics.
- Students will critically evaluate the reliability of scientific models and experimental data, recognizing the role of uncertainty and assumptions in scientific inquiry.
- Students will be able to design and execute scientific investigations, effectively communicating their findings and justifying conclusions based on evidence, laying the groundwork for future scientific research.

Students will know the following content:

- The definitions and distinctions between position, displacement, distance, speed, velocity, and acceleration.
- How to represent one-dimensional and two-dimensional motion mathematically and graphically.
- The SUVAT equations and their appropriate application for uniformly accelerated motion, along with their underlying assumptions.
- The independent horizontal and vertical components of projectile motion.
- The sources and expressions of measurement uncertainty, including absolute and percentage uncertainty.
- The principles of uncertainty propagation through simple mathematical relationships.
- The importance of appropriate units and significant figures in scientific reporting.

Students will develop the following skills:

- Representing motion using Cartesian coordinates, vectors, mathematical functions, and various motion graphs (position-time, velocity-time, acceleration-time).
- Interpreting the gradient and area of motion graphs to extract physical quantities.
- Selecting and applying appropriate SUVAT equations to solve kinematics problems.
- Formulating focused research questions and identifying variables for scientific investigations.

- Collecting, organizing, and analyzing quantitative data, including graphical analysis.
- Comparing experimental data with theoretical models and interpreting deviations.
- Evaluating limitations, assumptions, and sources of uncertainty in models and experiments.
- Communicating scientific findings effectively, justifying conclusions with evidence.
- Utilizing interactive mathematical models, simulations, and AI-supported tools for inquiry and data analysis.

Students will grasp the following concepts:

- Motion can be represented, modeled, and predicted mathematically, but all physical measurements and models inherently contain uncertainty and assumptions that must be evaluated.
- The interconnectedness of displacement, velocity, and acceleration as rates of change.
- The relationship between physical motion and its multiple representations (equations, graphs, vectors, numerical data).
- The distinction between precision and accuracy in measurements.
- That computational simulations are models, not direct evidence of reality, and require critical interpretation.
- The progression from simple position to complex motion analysis, incorporating uncertainty as an integral part of scientific understanding.

Content inquiry questions

- What are position, displacement, distance, speed, velocity and acceleration?
- How are motion quantities represented mathematically and graphically?
- What do the SUVAT variables represent?
- Under what conditions can the SUVAT equations be used?
- What is measurement uncertainty?
- How can uncertainty be expressed and propagated?

Skill inquiry questions

- How can a changing position be represented as a mathematical function?
- How are velocity and acceleration connected to changes in position?
- Why does the same physical motion appear differently on displacement-time, velocity-time and acceleration-time graphs?

Conceptual inquiry questions

- How reliable is a mathematical model of a physical system?
- When does an idealised model of motion stop being a useful representation of reality?
- Can computational simulations be considered evidence about the real world?

Action: Teaching and learning through inquiry

Formative assessment

Formative assessment will be embedded continuously throughout the unit to monitor student understanding and provide ongoing feedback. Examples include:

- **Concept checks:** Short questions asking students to predict outcomes before running simulations.
- **Interactive prediction tasks:** Students manipulate variables and explain observed effects.
- **Graph interpretation:** Students identify relationships and describe motion from graphs without immediate reliance on equations.
- **AI/Socratic dialogue:** Interaction with an AI Physics Tutor for targeted questioning based on student models, graphs, variables, and observations.
- **Digital laboratory notebook:** Students record predictions, observations, explanations, questions, and conclusions.
- **Data analysis tasks:** Students collect simulated or experimental data and analyze trends, gradients, intercepts, and deviations from models.
- **Uncertainty checkpoints:** Students identify and explain the impact of uncertainty in measurements before calculations.

Summative assessment

The summative assessment for this unit will be the **A1 Kinematics Investigation**. This individual quantitative investigation will allow students to demonstrate their cumulative understanding and skills by:

- Formulating a focused research question.
- Identifying variables.

- Developing a relevant mathematical model.
- Collecting or generating quantitative data, including measurement uncertainty.
- Analyzing the data.
- Comparing results with the mathematical model and interpreting deviations.
- Evaluating limitations and assumptions.
- Reaching a supported conclusion.

This investigation is designed to develop habits required for future IB scientific investigation work, assessing evidence of correct use of kinematic quantities, interpretation of motion graphs, appropriate selection and use of SUVAT equations, mathematical reasoning, treatment of uncertainty, and scientific communication.

Learning process

The unit will employ a highly interactive, inquiry-driven approach, progressing through the following learning experiences:

1. **From Position to Motion:** Students begin by manipulating coordinates to understand that motion occurs when position changes with time.
2. **Build Motion Mathematically:** Students construct and investigate simple displacement-time relationships (e.g., X=ut) through interactive variables, predicting and testing outcomes.
3. **Introduce Acceleration:** Students modify mathematical models to include acceleration (e.g., $X=ut+½at^2$) and explore its effects on motion and graphs.
4. **Connect Multiple Representations:** Students simultaneously examine physical motion, equations, graphs, vectors, and numerical data, exploring their interconnections.
5. **Projectile Motion:** Students construct horizontal and vertical components to investigate projectile trajectories by changing initial velocities, gravitational acceleration, and time.
6. **SUVAT Investigation:** Students explore the four SUVAT equations through physical scenarios, identifying knowns and unknowns, selecting appropriate models, and comparing predictions with simulations/data.
7. **Uncertainty Laboratory:** Students introduce uncertainty into measurements (distance, time, velocity, acceleration) and investigate its propagation through calculations.
8. **Computational Investigation:** Students use interactive simulations for repeated trials, data collection, and comparison of mathematical models with generated observations, including an introduction to Monte Carlo-style thinking.

This structured progression will ensure students develop a deep and nuanced understanding of kinematics, experimental design, and mathematical modeling.

Connections

Approaches to learning

- Thinking
  - Critical thinking
    - Interpret data
    - Draw reasonable conclusions and generalizations
    - Formulate factual, topical, conceptual, & debatable questions
    - Use models and simulations to explore complex systems and issues
  - Creative thinking
    - Design new machines, media, and technologies
    - Apply existing knowledge to generate new ideas, products, or Processes
  - Reflection
    - Reflect on competencies in the different ATL skills
    - Reflect on learning strategies and its impact on learning success
    - Reflect on previous learning experiences and implement new strategic approaches
  - Transfer
    - Apply skills and knowledge in unfamiliar situations
- Communication
  - Use a variety of speaking techniques to communicate with a variety of audiences in different contexts (to inform, describe, narrate, explain, persuade, and argue)
  - Use appropriate forms of writing for different purposes & audiences
  - Make inferences and draw conclusions
- Self-management
  - Organisation
    - Plan short- and long-term tasks to meet deadlines and goals by breaking down a larger task into specific steps
  - Affective
    - Practise analysing and attributing causes for failure

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- Research
  - Information literacy
    - Collect and analyse data to identify solutions and make informed decisions
    - Process data and report results
    - Evaluate and select information sources and digital tools based on their appropriateness and credibility to specific tasks
  - Media literacy
    - Analyze different media and news channels' points of view to identify bias and use triangulation of sources to verify sources
    - Understand the impact of media representations and modes of presentation

Details:

The unit will foster ATL skills through its inquiry-based approach and integrated use of technology:

- Thinking Skills (Critical and Creative):** Students will continuously apply critical thinking as they analyze data, interpret graphs, evaluate models, and identify assumptions. Creative thinking will be sparked as they design investigations, formulate hypotheses, and explore different representations of motion. The AI Physics Tutor will encourage deeper thinking through Socratic questioning.
- Research Skills (Information and Media Literacy):** Students will develop research skills by collecting quantitative data from simulations and experiments, evaluating the reliability of their measurements, and processing data to report results. They will also interpret computational models and media representations of physical phenomena.
- Communication Skills (Speaking, Writing, Visual Interpretation):** Clear communication will be essential as students explain their reasoning, justify conclusions with evidence, and use scientific language to describe observations. They will practice representing physical systems mathematically, and through graphs and equations, honing their visual interpretation skills. The digital laboratory notebook will serve as a key tool for written communication.
- Self-Management Skills (Organization and Reflection):** Students will organize their investigations, manage their data, and maintain detailed digital laboratory notebooks. Reflection will be crucial as they monitor their own understanding, evaluate their problem-solving strategies, and revise their explanations based on new evidence or insights into uncertainty.

Differentiation Approach

- Content
- Product

Details:

Your unit plan incorporates robust differentiation strategies across three key areas:

- **Support:**
  - **Scaffolded variable identification:** Providing structured guidance to help students identify independent, dependent, and controlled variables.
  - **Visual representations:** Utilizing diagrams, graphs, and interactive simulations to make abstract concepts more accessible.
  - **Guided prompts:** Offering specific questions or sentence starters to assist with analysis and explanation.
  - **Partially completed models:** Providing foundational models that students can build upon, reducing initial cognitive load.
  - **Structured data tables:** Guiding students in organizing their data effectively.
  - **AI-generated Socratic hints:** Employing AI as a tool to offer targeted, thought-provoking questions.
  - **Multiple representations of the same physical situation:** Presenting concepts through various lenses (e.g., equations, graphs, physical demonstrations) to cater to different learning styles.
- **Extension:**
  - **Derive relationships between variables:** Encouraging advanced students to mathematically derive kinematic relationships rather than just applying them.
  - **Investigate limitations of SUVAT:** Challenging students to explore scenarios where the SUVAT equations break down or require modifications.
  - **Compare ideal and non-ideal motion:** Analyzing the conceptual impact of factors like air resistance that are often ignored in idealized models.
  - **Introduce air resistance conceptually:** Exploring the qualitative effects of fluid resistance on projectile motion.
  - **Perform sensitivity analysis:** Investigating how small changes in input parameters affect the outcomes of a model.
  - **Use computational approaches to propagate uncertainty:** Employing more advanced computational tools for uncertainty analysis.
  - **Design independent investigations:** Empowering students to develop and execute their own original kinematics experiments.
- **Student Choice:**
  - **Physical context:** Allowing students to choose the real-world scenario for their investigations (e.g., vehicle acceleration, projectile motion, free-fall).

- **Variables:** Giving students agency in selecting the variables they wish to manipulate and measure.
- **Model:** Offering choices in the mathematical or computational models they use to represent motion.
- **Data-collection method:** Providing options for how they gather their quantitative data.
- **Representation:** Allowing flexibility in how they visually and mathematically present their findings.
- **Investigation question:** Empowering students to formulate their own research questions, fostering deeper ownership and inquiry.

Language and Learning Connection

- Demonstrating proficiency
- Scaffolding for new learning
- Acquisition of new learning through practice
- Activating background knowledge

Details:

This unit provides numerous opportunities for students to develop their language and learning skills in the context of physics:

- **Subject-Specific Vocabulary:** Students will acquire and use precise terminology related to kinematics (e.g., displacement, velocity, acceleration, uncertainty, propagation) through explicit instruction and consistent application in discussions, written work, and problem-solving.
- **Interpretation of Scientific Texts:** Students will practice interpreting various forms of scientific communication, including mathematical equations (SUVAT), graphical representations (position-time, velocity-time, acceleration-time graphs), and written descriptions of experimental procedures and results.
- **Mathematical Literacy:** The unit heavily relies on mathematical language and symbolism. Students will develop fluency in translating physical situations into mathematical models and vice versa, understanding the meaning embedded in equations and variables.
- **Scientific Communication:** Through their digital laboratory notebooks, investigation reports, and interactions with the AI Physics Tutor, students will refine their ability to articulate scientific ideas clearly, justify conclusions with evidence, and communicate complex concepts to different audiences.
- **Multimodal Learning:** The use of interactive simulations, Desmos-based modeling, and visualisations will cater to diverse learning styles, allowing them to grasp concepts through visual, kinesthetic, and auditory channels, reinforcing their understanding of the language of physics.
- **Critical Reading and Analysis:** Students will critically analyze problem statements, experimental procedures, and the results of their investigations, enhancing their ability to extract key information and evaluate scientific claims.
- **Socratic Dialogue and Questioning:** The AI-supported questioning will encourage students to articulate their thinking, clarify their understanding, and engage in deeper linguistic processing of scientific concepts.

TOK Connection

Areas of knowledge

- The natural sciences
- Mathematics

Concepts

- Evidence
- Interpretation
- Justification
- Objectivity
- Perspective
- Truth

Details:

This unit offers rich opportunities to explore various aspects of the Theory of Knowledge, particularly within the **Natural Sciences** and **Mathematics** as Areas of Knowledge:

- **The Nature of Scientific Models:** Students will critically examine how mathematical models (like the SUVAT equations) represent reality. This will lead to discussions about:
  - **Truth and Interpretation:** How do we determine the "truth" of a scientific model? What are the implications of the fact that all models are approximations, and how do we interpret the relationship between the model and the physical world?
  - **Evidence and Justification:** What constitutes valid evidence in physics? How do we justify claims about motion based on experimental data, especially when considering uncertainty? How do simulations serve as evidence, and what are their limitations?

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    - **Objectivity and Perspective:** To what extent can scientific observations and interpretations be truly objective? How do different representations (graphs, equations, physical motion) offer varying perspectives on the same phenomenon?
- **The Role of Uncertainty in Knowledge:** The explicit focus on measurement uncertainty and its propagation will prompt discussions on:
    - **Certainty:** Can we ever achieve absolute certainty in scientific knowledge, or is all empirical knowledge inherently probabilistic?
    - **Limitations of Knowledge:** How does uncertainty define the boundaries of what we can know about the physical world?
- **Technology and Knowledge:** The extensive use of interactive simulations, Desmos, and AI-supported questioning will allow for reflection on:
    - The role of technology in generating, processing, and validating scientific knowledge.
    - The ethical implications of using computational models and AI in scientific inquiry.

CAS Strands

- Creativity

Details:

This Kinematics unit provides several avenues for students to engage with the **Creativity** strand of CAS:

- **Exploring Ideas and Designing Investigations:** Students will engage in creative thinking as they formulate focused research questions, identify variables, and design their individual kinematics investigations. This involves original thought in conceptualizing experiments to test specific hypotheses.
- **Developing Mathematical Models:** The process of translating physical phenomena into mathematical representations using Desmos and other tools encourages creative problem-solving and the development of interpretive products. Students will explore and extend ideas about how mathematical functions can model real-world motion.
- **Innovative Use of Technology:** Utilizing interactive simulations, AI-supported questioning, and computational tools for data analysis and visualization fosters creativity in approaching scientific inquiry and understanding.
- **Interpreting and Representing Findings:** Students will creatively communicate their findings through various means, including graphs, written explanations, and scientific arguments, demonstrating an interpretive product of their learning.
- **Problem-Solving and Adaptability:** Encountering and addressing issues during data collection, interpreting deviations from models, and proposing improvements to investigations will require creative and adaptive thinking.

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