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General Information

Lesson Title: Mathematical Analysis of Uniform Motion Using Digital Tools

Subject(s): AP Physics 1: Algebra-Based

Grade/Level/Setting: 10th-11th Grade / AP Level / Laboratory Setting
Unit Position: Day 8 of 11 in One-Dimensional Motion Unit

Prerequisite Skills/Prior Knowledge:

What do your students already know or what do they need to know about the selected topic to successfully participate in the lesson?

- Differences between uniform and accelerated motion from Days 3-7
- Position-time and basic velocity concepts
- Video recording and basic data analysis techniques
- Computer navigation and file management
- Basic graphing and pattern recognition skills

Common Misconception Addressed: Students often confuse velocity and acceleration, thinking they are the same concept. This lesson specifically distinguishes between these quantities through technological analysis.

Three Dimensions

Disciplinary Core Ideas:

Provide a description of the disciplinary core ideas on which the lesson will focus.

PS2.A - Forces and Motion: Acceleration is the rate of velocity change caused by net force. Students develop precise understanding of acceleration as a fundamental quantity distinct from velocity, connecting motion analysis to force concepts.

Science & Engineering Practices:

Identify the science and engineering practices the lesson will emphasize and explain how the science and engineering practice(s) you chose will support student understanding of the scientific concepts covered in the lesson.

SP-5: Using Mathematical and Computational Thinking - Students use advanced technological tools for precision measurement and calculation beyond human capability.

SP-4: Analyzing and Interpreting Data - Students interpret multiple simultaneous graphs (position, velocity, acceleration) to understand motion relationships.

Crosscutting Concepts:

Identify the crosscutting concept(s) used in the lesson and explain how the crosscutting concepts you chose will support student

understanding of the scientific concepts covered in the lesson.

Patterns - Linear velocity-time graphs reveal constant acceleration, showing predictable mathematical relationships in accelerated motion.

Cause and Effect - Net force (cause) produces acceleration (effect), establishing foundation for Newton's Laws in subsequent units.

Integration:

Explain how the three dimensions will work together in this lesson to support students in making sense of phenomena and/or to design solutions to problems.

Students use advanced mathematical tools for precision analysis (SEP), identify patterns that reveal cause-effect relationships (CCC), while developing understanding of acceleration as the link between motion and forces (DCI).

Standards and Objectives

State/National Academic Standard(s):

AP Physics 1 Learning Objectives:

- **LO 1.D.1:** The student is able to create representations of the motion of an object with constant acceleration (College Board, 2024)
- **LO 1.B.1:** The student is able to calculate the average velocity of an object over a time interval (College Board, 2024)

Science Practices:

SP-5: Using Mathematical and Computational Thinking - Advanced technological analysis (College Board, 2024)

SP-4: Analyzing and Interpreting Data - Multiple graph interpretation (College Board, 2024)

Learning Objective(s):

Identify what students will accomplish by the end of the lesson; needs to align with the state or Common Core State Standards and needs to be measurable (condition, behavior, and criterion).

Condition: Using Vernier Video Analysis software and recorded zipline motion videos

Behavior: Students will use professional video analysis software to calculate instantaneous velocity,

define acceleration as rate of velocity change, and connect acceleration concepts to force

Criterion: Successfully complete video analysis with 95% accuracy in measurements, correctly define acceleration in terms of velocity change, and explain the connection between acceleration and net force

Materials

What materials will the teacher and the students need in order to complete the lesson?

- Zipline motion video recordings from Day 6
- Computer workstations with Vernier Video Analysis software
- Reference materials for physics definitions
- Calculators for verification
- Graph paper for manual checking

Technology

How will you use technology to enhance teaching and learning? (Optional: Use the SAMR model to explain the technology integration strategies you plan to use.)

- Vernier Video Analysis Software enables analysis impossible without technology:
  - Frame-by-frame position tracking with sub-pixel accuracy
  - Automatic velocity and acceleration calculations in real-time
  - Multiple simultaneous graph generation (position, velocity, acceleration vs. time)
  - Precision measurements beyond human capability
  - Statistical analysis and curve fitting
  - Export capabilities for further analysis

  This technology redefines motion analysis by making previously impossible measurements accessible to students, fundamentally changing how motion can be understood and analyzed.

Safety Concerns

Identify any safety concerns and necessary safety precautions that should be taken to ensure a safe learning environment.

Minimal safety concerns for this computer-based analysis lesson:

- Digital citizenship: Ensure appropriate use of specialized software and school technology policies
- Data management: Proper file saving and backup procedures to prevent data loss
- Ergonomics: Encourage proper posture during extended computer analysis work
- Software protocols: Follow proper login and logout procedures for specialized software

Language Demands

*Specific ways that **academic language** (vocabulary, functions, discourse, syntax) is used by students to participate in learning tasks through reading, writing, listening, and/or speaking to demonstrate their understanding.*

Language Function:

The content and language focus of the learning task represented by the active verbs within the learning outcomes. Common

language functions may include predicting, summarizing, questioning, or interpreting. (Choose one)

Defining and Distinguishing - Students will define acceleration precisely and distinguish it from velocity using mathematical and conceptual reasoning.

Vocabulary:

Includes words and phrases that are used within disciplines including: (1) words and phrases with subject-specific meanings that differ from meanings used in everyday life (e.g., table); (2) general academic vocabulary used across disciplines (e.g., compare, analyze, evaluate); and (3) subject-specific words defined for use in the discipline.

- **Instantaneous velocity:** Velocity at a specific moment in time
- **Acceleration:** Rate of change of velocity with respect to time
- **Net force:** The sum of all forces acting on an object
- **Frame-by-frame analysis:** Examining motion by viewing individual video frames
- **Real-time calculation:** Immediate computation of results during analysis
- **Precision measurement:** High-accuracy data collection using technological tools

Discourse and/or Syntax:

Discourse includes the structures of written and oral language, as well as how members of the discipline talk, write, and participate in knowledge construction. Syntax refers to the set of conventions for organizing symbols, words, and phrases together into structures (e.g., sentences, graphs, tables).

Students will use precise scientific discourse including:

- Definitional language: "Acceleration is defined as the rate of change of velocity"
- Causal connections: "Net force causes acceleration, which causes velocity change"
- Comparative statements: "Unlike velocity, acceleration measures how velocity changes"
- The slope of a velocity vs time graph represents acceleration

Planned Language Supports:

The scaffolds, representations, and pedagogical strategies teachers intentionally provide to help learners understand and use the concepts of language they need to learn within disciplines.

- Physics vocabulary reference cards with precise definitions and units
- Concept map templates showing relationships between force, acceleration, and velocity
- Mathematical expression guides for rate-of-change concepts Sentence frames for scientific definitions ("_____ is defined as _____")
- Think-pair-share protocols for concept clarification discussions

5E Instructional Strategies and Learning Tasks

	Activity Description/Teacher	Student Actions
Engagement: (5 minutes)	**Activity Description: Velocity vs. Acceleration Concept Check** Present scenarios to distinguish velocity and acceleration concepts, address common misconceptions, activate prior knowledge about motion analysis	Respond to concept questions, identify examples of high velocity with low acceleration and vice versa, prepare for precise definitions
Exploration: (25 minutes)	**Activity Description: Vernier Video Analysis Software Tutorial and Hands-on Analysis** Demonstrate software login and basic functions, provide step-by-step guidance for video analysis, monitor student progress and provide technical support	Log into Vernier software, load Batman motion videos, practice frame-by-frame tracking, explore automatic calculation features
Explanation: (15 minutes)	**Activity Description: Acceleration Definition and Force Connection Introduction** Define acceleration using software-generated velocity-time graphs, explain rate-of-change concept, introduce connection between acceleration and net force	Record precise definition of acceleration, analyze velocity-time graphs for linear patterns, begin understanding force-acceleration relationship
Elaboration:	*Integrated into Exploration phase during software analysis*	
Evaluation: (5 minutes)	**Activity Description: Acceleration Calculation Accuracy and Force Connection Understanding** Verify student acceleration calculations, assess understanding of velocity-acceleration distinction, evaluate comprehension of force connection	Complete acceleration calculations from velocity data, demonstrate understanding of concept differences, explain force-acceleration connection

Differentiated Instruction

Consider how to accommodate for the needs of each type of student. Be sure that you provide content specific accommodations that help to meet a variety of learning needs..

Gifted and Talented:

- Advanced analysis: Explore higher-order derivatives and jerk (rate of acceleration change)
- Multiple motion types: Analyze videos with varying acceleration patterns
- Software mastery: Become peer tutors for advanced software features
- Research connections: Investigate how professional physicists use similar analysis tools

ELL:

- Visual software guides: Provide step-by-step screenshots with minimal text
- Bilingual vocabulary: Offer physics terms in native language when available
- Collaborative support: Pair with fluent English speakers for software navigation
- Hands-on emphasis: Focus on software manipulation with visual confirmation of concepts
- Simplified definitions: Use clear, concrete language for acceleration concept

Students with Other Special Needs:

- Learning disabilities: Provide software navigation checklists and structured analysis procedures
- Visual impairments: Use screen reader compatible software settings and audio descriptions
- ADHD: Break software tutorial into short segments with frequent check-ins
- Autism spectrum: Provide clear step-by-step procedures and consistent software interface
- Fine motor difficulties: Utilize keyboard shortcuts and automated features when available

Assessment

Formative:

(Describe how you will monitor, support, and extend student thinking.)

- Software proficiency demonstration: Observation of student ability to navigate and use Vernier Video Analysis effectively
- Acceleration calculation accuracy: Real-time verification of mathematical results and proper units
- Concept distinction evaluation: Assessment of student ability to differentiate velocity and acceleration
- Force connection understanding: Quick verbal checks of acceleration-force relationship comprehension

Summative:

(Describe how you will assess student progress toward achieving the lesson objectives.)

- Video analysis project completion: Evaluation of complete motion analysis including position, velocity, and acceleration graphs
- Mathematical accuracy: Assessment of calculation precision and proper unit usage
- Conceptual understanding: Evaluation of acceleration definition and its distinction from velocity

- Technology integration: Assessment of effective use of advanced analysis tools