Standards and Assessment Development

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Multiple-choice assessments are often associated with lower-level cognitive skills such as recall of facts; however, when carefully designed they can also be useful for assessing higher-order thinking skills and are a valuable tool for assessing student understanding in STEM education (Lenchuk & Ahmed, 2021; Mitra, 2022). Therefore, this paper will present a rationale for the development of a summative multiple-choice exam that will be used to assess the learning objectives from a one-week physics unit on the topic of accelerated motion. The standards and objectives on which the following Table of Test Specifications and Curriculum Map are based have been adapted from the International Baccalaureate (IB) Physics curriculum. The intent of using these tools in the development of unit assessments and the selection of unit activities is so that a balanced approach can be adopted across all aspects of assessment.

Table of Test Specifications

A Table of Test Specifications (Table 1) was developed for a 10-item, summative, multiple-choice exam to be used at the end of the unit of study. The three Bloom's Taxonomy Cognitive Levels in the table were determined by comparing the verbs in the standard and the three objectives with those in a table of verbs based on the revised Bloom's Taxonomy (Northern Illinois University Center for Innovative Teaching and Learning, 2020). The verbs "sketch" and "construct" were not included in the analysis as they are not possible to assess during a multiple-choice examination. Although the verb "determine" is categorised as part of the "Evaluating" cognitive level, in the context of the unit (processing experimental data to estimate a value for acceleration due to gravity), "Analysing" was considered to be the more appropriate cognitive level to assign it to (in IB Physics, evaluating is usually taken to mean evaluating the validity and reliability of a measurement or result). The number of questions for each cognitive level of the taxonomy in the table was determined by considering the major instructional emphasis of the unit and the types of multiple-choice questions that are typically used to assess each of the three objectives. The underlined verbs in each objective were taken as merely suggestive (as opposed to prescriptive) of a particular cognitive level. For example, students could be asked to interpret a motion graph and then use the values thus obtained to solve for an unknown quantity, and so questions that assess the first objective can also be at the "Applying" cognitive level. Similarly, some questions about the motion of objects in freefall will simply require students to *apply* the SUVAT equations in a freefall context, and thus would not be considered as questions at the "Analysing" cognitive level. Overall, it is appropriate that the majority of the test items (60%) are at the Applying cognitive level, since the major instructional emphasis of the unit is on the application of physics principles to solving motion problems.

Table 1: Test Specifications

Standard: Solve problems using equations of motion for uniform acceleration, sketch and interpret motion graphs, and determine the acceleration of free-fall experimentally.				
Title of Unit of Study: Accelerated Motion				
Grade Level: 11	**Content Area:** Physics			
Total Points: 10	**Type of Items:** Multiple Choice			
	Bloom's Taxonomy Cognitive Levels Number/ Percent of Items Per Level			
Objectives	**Level: Understanding**	**Level: Applying**	**Level: Analysing**	**Total/ Percent**
Given the relevant parameters, construct or interpret motion graphs of constant acceleration situations (Understanding).	2 (20%)	2 (20%)		4 (20%)
Apply the SUVAT equations to determine (solve for) unknown quantities in motion problems (Applying).		3 (30%)		3 (30%)
Analyse the motion of objects in freefall in order to predict their future positions and velocities (Analysing).		1 (10%)	2 (20%)	3 (30%)
Total:	2 (20%)	6 (60%)	2 (20%)	10/100%

Curriculum Map

A curriculum map (Table 2) for the unit of study was developed by first mapping six unit-specific essential questions based on McTighe and Wiggins' six facets of understanding (2005) to the knowledge and skills listed in the relevant section of the IB Physics curriculum guide. Activities and assessments were then selected to achieve a balance of experimental and mathematical approaches to the application of physics principles and reflect the mixture of cognitive levels and objectives represented in Table 1. The selected assessments reflect the major instructional emphasis of the unit – that is, applying common physics principles to a variety of situations - since they assess a balanced mixture of graphical, algebraic, and experimental approaches. To ensure that the selected activities meet the needs of diverse learners, examples of active learning were adapted from Milman (2019) for the unit-specific context. Although Milman's approaches are intended for use in online courses, many of the principles are equally applicable to engaging diverse learners in a face-to-face classroom, especially in today's increasingly hybrid learning environment.

Table 2: Curriculum Map

<table>
<tr><td colspan="2">Standard: Solve problems using equations of motion for uniform acceleration, sketch and interpret motion graphs, and determine the acceleration of free-fall experimentally.</td></tr>
<tr><td colspan="2">Learning Objectives:
1) Given the relevant parameters, construct or <u>interpret</u> motion graphs of constant acceleration situations.
2) Apply the SUVAT equations to determine (<u>solve</u> for) unknown quantities in motion problems.
3) <u>Analyse</u> the motion of objects in freefall in order to predict their future positions and velocities.</td></tr>
<tr><td>Grade Level: 11</td><td>Content Area: Physics</td></tr>
<tr><td>Unit Title: Accelerated Motion</td><td>Length of Unit: One week</td></tr>
<tr><td colspan="2">Description of Unit of Study: students will study the physics of the motion of objects with constant acceleration both experimentally and mathematically. Mathematical approaches will include both graphical and algebraic methods, and experimental approaches will include the use of simulations, video analysis and hands-on measurement.</td></tr>
</table>

Content and/or Essential Questions	Knowledge and Skills	Suggested Assessments	Activities	Resources
How are motion graphs connected to the SUVAT equations? What does the area under a velocity-time graph represent? How are the SUVAT equations used to create braking distances? What are the limits of the SUVAT equations' applicability? How might someone in Galileo's time feel about their world view being challenged? How do we know that Galilean kinematics are an accurate model of reality?	Knowledge: Distance and displacement Speed and velocity Acceleration Graphs describing motion Equations of motion for uniform acceleration Skills: Determining instantaneous and average values for velocity, speed, and acceleration. Solving problems using equations of motion for uniform acceleration. Sketching and interpreting motion graphs.	Day 1: prior knowledge test (constant velocity motion) Day 2: formative motion graph MCQ quiz Day 3: formative SUVAT equations quiz Day 4 and 5: performance task - estimate the acceleration due to gravity using data collected via a method of the students' choice including graph and discussion of accuracy and limitations. Day 5: summative, end-of-unit assessment	Hyperloop velocity-time graph analysis Sketching motion graphs of various freefall and rolling motion situations Connecting the SUVAT equations with motion graphs (PhET "The Moving Man" simulation + Geogebra file with sliders) Designing a reaction timer using freefall distances of a metre ruler Apollo mission feather and hammer freefall video analysis; discussion of how Galileo could "prove" this result without modern instruments.	Student laptops with open internet access Metre sticks and stopwatches Various freefall experiment equipment: photogates, stands and clamps, marbles, golf balls, ramps and carts, etc.

Conclusion

Considered together, my assessment choices provide an appropriate balance of formative and summative assessment and of different assessment types. The prior knowledge test will allow me to address any misconceptions or skill gaps before introducing the main idea of the unit, acceleration as a rate of change of velocity with time. The two formative assessments will allow students to become familiar with the format of the summative end-of-unit assessment while at the same time allowing me to adjust subsequent instruction. Devoting most of the final two days to collecting and processing experimental data is consistent with the nature of physics as an experimental science and honours the intent and cognitive level of the verb “analyse” in Learning Objective 3. Finally, as per Table 1, the summative end-of-unit assessment has been carefully designed to assess a balance of learning objectives and cognitive levels.

References

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