Instruction and standards-referenced grading in a 9th grade conceptual physics classroom

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Abstract

In recent years, a radical method of assessing students has been gaining popularity. An increasing number of school systems in Iowa and nationwide are implementing standards-referenced grading (Stegmeir, 2014). In standards-referenced grading, grades are determined only by academic factors. This makes grades more accurate, fair, and useful for students and parents. While standards-referenced grading can offer many benefits, stakeholders can often resist making the change (Stegmeir, 2014). The goal of this project is to provide an example of exemplary physics instruction that is assessed using standards-referenced grading in a 9th grade conceptual physics classroom.

INSTRUCTION AND STANDARDS-REFERENCED GRADING IN A 9TH GRADE CONCEPTUAL PHYSICS CLASSROOM

Curriculum Development Project

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Chapter 1: Introduction

In recent years, a radical method of assessing students has been gaining popularity. An increasing number of school systems in Iowa and nationwide are implementing standards-referenced grading (Stegmeir, 2014). In standards-referenced grading, grades are determined only by academic factors. This makes grades more accurate, fair, and useful for students and parents. While standards-referenced grading can offer many benefits, stakeholders can often resist making the change (Stegmeir, 2014). The goal of this project is to provide an example of exemplary physics instruction that is assessed using standards-referenced grading in a 9th grade conceptual physics classroom.

What is standards-referenced grading? For the purposes of this project, standards-referenced grading will be defined as an assessment system in which students are graded solely upon their proficiency in reference to well-defined standards (Marzano, 2010). Standards-referenced grading aims to eliminate the role of non-academic factors in grades, such as behavior and attendance.

Why utilize standards-referenced grading? Reeves (2011) explains that effective feedback should be accurate, fair, specific, and timely. A standards-referenced grading system is meant to make grading as fair as possible. A grade should communicate how much a student has learned, and thus should only reflect abilities related to material listed in the course curriculum (Wormeli, 2014). A 4-3-2-1 grading scale that is often utilized with standards-referenced grading is also meant to make a grading system fairer. If a student neglects to do an assignment in a 90-80-70-60 grading system, a 0% score will hurt that student's grade more than a 100% will help them (Reeves, 2004).

This project includes a literature review of the “why’s” and the “how-to’s” of standards-referenced grading, as well as an introductory physics unit at the 9th grade level called Measurement and Motion. The unit contains appropriate standards from the Des Moines Public Schools curriculum, grading scales, and assessments that are aligned to the standards. This creative component project is highly significant to the Conceptual Physics Data Team at my school, as well as anyone looking to utilize standards-referenced grading. Our school is in the process of implementing standards-referenced grading across all curricular areas. Each data team (e.g. Geometry, English 9) at our school was asked to implement standards-referenced grading in either fall 2012, spring 2013, or fall 2013. After learning how to establish standards-referenced grading through professional development trainings in the fall of 2012, our conceptual physics team chose to implement during the spring semester of 2013.

On a larger scale, the school district is moving all comprehensive high schools to a standards-referenced grading system over 4 years, starting with all 9th grade courses in the 2014-15 school year. Most courses at North High School adopted standards-referenced grading in 2012-2013, so we have become a district leader in implementing the grading system. However, over the past three years, our experience was similar to asking a person to define “science;” the more you know about the subject and are able to practice it, the more in-depth and confusing the answer becomes. The literature review provides a better understanding of standards-referenced grading and can serve as a guide for developing such a program at other schools or disciplines.

The product of this creative component is a ready-to-use introductory unit from the Des Moines Public School's Conceptual Physics Curriculum, entitled Measurement and Motion. This unit includes:

- Lesson summaries
- Daily Power Point slides to guide students through inquiry-based laboratory activities
- Accompanying worksheets/lab data tables
- Assessments that are aligned to course standards
- Standards from the Des Moines Public Schools Conceptual Physics curriculum
- Grading scales to assign grades based on the standards.

Chapter 2: Literature Review

How Students Learn

When designing science curriculum, an important question to ask is “how do people learn science?” A constructivist approach to teaching and learning science is a widely accepted philosophy that has been thoroughly researched. In the constructivist classroom, students reconstruct existing concepts through interactions with their environment (Wadsworth, 2004). This *defines* learning to a constructivist. In this definition, the “environment” includes other people (Trowbridge, Bybee, & Carlson-Powell, 2004), and makes learning a social process. Students do not passively receive information in a constructivist classroom (Wheatley, 1991). In the science classroom, learning focuses on the natural world. As a physics teacher, it is my job to provide students opportunities to interact with the natural world so they can develop their own understandings. In short, it is my job to guide students in deciding where to look, but not telling them what to see.

The main premise behind constructivism is that learners hold preconceptions that they use to make sense of new experiences and information (Brooks & Brooks, 1999). Learning occurs when there is a change in the existing ideas. This can be new information that is added or a change in what was previously known (Appleton, 1997). French psychologist Jean Piaget described the process of changing preconceptions into new knowledge in depth. He thought of the human mind as a set of cognitive structures, called schemata, that help us make sense of the world. As we go through life and gain experiences, the schemata become more complex (Brooks & Brooks, 1999).

When a learner encounters new information, it is compared to the existing cognitive structures through a process called assimilation (Wadsworth, 2004). If the new information matches with current “known” information, the learner returns to a state of equilibrium, and the learner’s thinking/knowledge do not change and can even be reinforced (which is a bad thing if the thinking was incorrect). If the input does not match with existing schemata, the learner enters a state of disequilibrium. At this point, the existing schema may change to accommodate the new information, or the learner may create an entirely new schema for the new stimulus. These processes are called accommodation. Some would argue that the creation or modification of cognitive structures is the essence of exactly what learning is. Piaget would say learning cannot occur unless the learner has experienced cognitive disequilibrium: people constantly strive for cognitive equilibrium (Wadsworth, 2004).

How can a teacher take advantage of these understandings to help their students learn? Brooks and Brooks (1999, pp. 104-112) offered several suggestions on becoming a constructivist teacher. Their suggestions included:

- Using raw data along with manipulative, interactive, and physical materials.
- Using cognitive terminology such as “classify,” “analyze,” “predict,” and “create” when framing tasks.
- Allowing student responses to drive lessons, shift instructional strategies, and alter content.
- Inquiring about students’ understandings of concepts before sharing their own understanding of those concepts.
- Encouraging students to engage in dialogue, both with the teacher and with one another.
- Encouraging student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other.
- Engaging students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion.

In part, these characteristics of constructivist classrooms also describe several important characteristics of inquiry-driven classrooms, which also describe my own physics teaching. If constructivism describes how people learn, inquiry describes how to teach in a constructivist manner. Inquiry is both a process that is used by scientists to explain the natural world and a method used by students and teachers to learn and teach science. (National Research Council, 1996).

Inquiry is important science process, and the National Research Council has long encouraged inquiry-centered classrooms (National Research Council, 1996). With the Next Generation Science Standards gaining support, some science educators are concerned that inquiry is not included, or at least does not play as big of a role. Although inquiry is not the focal point in the Next Generation Science Standards, inquiry is still one of many important science skills that should be practiced in science classrooms (NGSS Lead States, 2013). Either way, inquiry is a very powerful tool for teaching and learning science.

As with any skill, the more inquiry is practiced, the better students will become. If students are to learn how to do science, they must engage in scientific practices themselves. National Science Education Standards note that inquiry based on student-generated questions is the central strategy for teaching science. (National Research Council, 1996).

Rather than a single scientific practice or method of teaching and learning science, inquiry really is more of a spectrum ranging from very teacher-directed to very student-centered (Martin-Hansen, 2002). Each type of inquiry has its own advantages and disadvantages, and different types of inquiry can be used for different purposes in a science classroom (Martin-Hansen, 2002). Types of inquiry include:

Structured Inquiry: inquiry that is mainly directed by the teacher. Structured inquiry can come in the form of cookbook investigations.

Guided Inquiry: inquiry in which the teacher provides the question for the investigation, but it is up to the students to decide (perhaps with the teacher's assistance) how to proceed with the investigation.

Open or Full Inquiry: a student-centered approach that includes a student-driven question and student-designed investigation.

As stated above, the National Science Education Standards assert that open-inquiry is the most effective method of science teaching and learning, although they do not advocate for "all inquiry, all the time." Time is a limiting factor in a classroom, and open-inquiry simply takes longer (National Research Council, 2000). Teachers should find a balance and select the appropriate method of teaching and learning that best suits their class at that time (National Research Council, 2000).

Each type of inquiry has advantages and disadvantages and thus has an appropriate time and place in the science classroom. It is important to find balance. In an education system where the teacher is responsible for teaching about specific standards and is held accountable for student performance on these standards, open-inquiry can be viewed as an inefficient way to cover course material. Without providing questions or topics for investigations, students will often choose focus on topics not related to state- and district-mandated standards. When used appropriately, guided inquiry is an effective method for teaching and learning science in an efficient manner. When using guided inquiry, teachers provide students with a question or topic for an investigation, which students carry out. Also, particularly at the beginning of the year, students with less inquiry experience often need scaffolding on good scientific practices

(National Research Council, 2000). At the beginning of the year, more structure is often needed and can be given to students, with a subsequent "gradual release of responsibility" throughout the course as students gain more skill in science practices (College Board, 2014).

Quality instruction is not the only component of an effective science classroom. After (and during) the learning process, students must be assessed on what they have learned. Standards-referenced grading is an effective way to assess students which my school has recently implemented across the building.

Rationale for Standards-Referenced Grading

The need for grading reform is obvious, in part because traditional grades are an unreliable form of measurement. For example, differences in grading policy between teachers of the same course in the same building can create wild variations in student grades (Guskey, Swan, & Jung, 2001). Due to the unreliability of traditional grading systems, a growing amount of schools and districts are transitioning to either standards-referenced or standards-based grading (Scriffiny, 2008). Standards-referenced grading is an assessment system in which students are graded upon their proficiency (and only their proficiency) in reference to well-defined standards (Scriffiny, 2008). The final grade is then a representation of what the student knows and is able to do, rather than a representation of how nice the kid is, how well- or poorly-behaved they are, or whether they perform better than their peers (such as in a norm-referenced or "curved" grading system) (O'Connor, 2009).

Before entering into a deep conversation about grading, it is necessary to highlight the subtle difference between standards-based and standards-referenced grading systems. Both tie assessment to standards, but the primary difference is in how the student progresses through the standards. In a standards-based system, the student does not move to the next level until he/she demonstrates proficiency, as a opposed to a standards-referenced system, in which the student moves on to the next grade level regardless of proficiency (Marzano, 2010). Many schools that claim to use standards-based grading actually use standards-referenced grading.

Why use standards-referenced grading as opposed to a traditional grading system? To answer this, we must first ask "what is the purpose of grading?" There are several reasons for grading, including communication, fostering student self-assessment, sorting and selecting, and motivation and punishment. Of all these reasons, the primary purpose of grading is to communicate achievement and offer feedback (O'Connor, 2011, Reeves, 2011).

One advantage of using standards-referenced grading is it makes grades more meaningful. Scriffiny (2008) suggested that giving a definition to an A, B, C, D, and F gives that letter grade more meaning. For example, an A doesn't mean much if it is not defined, however if it was communicated to stakeholders that an A means "the student has completed proficient work on all course objectives and advanced work on some objectives," it becomes more meaningful. When clear learning goals are established, standards-referenced grading offers important information about student achievement and performance (Guskey, 2001).

Breaking down a letter grade into individual standards also makes grading more meaningful. While many schools require that a single grade is reported at the end of a term, grading can still be broken down into individual standards. The reasoning is that a single letter grade offers no information about what is specifically learned. In a standards-referenced grading system, a report card will typically break down each subject area into individual standards. It is then clear where the student is proficient and where they struggle. For example, "Jimmy is proficient on the standard about electrical circuits, but is still progressing on the standard about electromagnetism," is more valuable than "Jimmy has a C." Using the standards-referenced report card, Jimmy and his parents know exactly what he needs to work on.

An important aspect of standards-referenced grading is selecting rigorous standards. High standards for students will improve achievement (Figlio & Lucas, 2003). This much is commonly accepted in the education community. According to the Iowa Core Characteristics of Effective Instruction, lessons should be "cognitively demanding and challenge students to apply the essential concepts and skills to real-world, complex, and open-ended situations" (Iowa Department of Education, 2012). High expectations for students can improve achievement, but when utilized correctly, standards-referenced grading promises even larger gains.

When it comes to standards-referenced grading, a common thread across the literature is that students can achieve at higher levels if they are graded only on what they know and what they can do. "Standards-based grading is based on the principle that grades should convey how well students have achieved standards. In other words, grades are not about what students *earn*; they are about what students *learn*" (Brookhart, 2011, p. 12).

O'Connor (2011) suggested several guidelines for making sure grades are about how well students have achieved a given standard:

1. Don't include student behaviors (effort, participation, adherence to class rules, etc.) in grades; include only achievement.
2. Don't reduce marks on "work" submitted late; provide support for learner.
3. Don't give points for extra credit or use bonus points; seek only evidence that more work has resulted in a higher level of achievement.
4. Don't punish academic dishonesty with reduced grades; apply other consequences and reassess to determine actual level of achievement.

5. Don't consider attendance in grade determination; report absences separately.
6. Don't include group scores in grades; use only individual achievement evidence.

These are widely accepted guidelines for standards-referenced grading. Teachers must accept that behaviors should not factor into a student's grade. We should not base student grades on behavior, attendance, extra credit (which is often unrelated to student learning), or any other factor. A grade should be based on what a student knows. This will actually help students produce high-quality work and have a higher degree of self-sufficiency (Scriffiny, 2008).

In my school, I have observed first-hand that several of these guidelines are hard for many teachers (myself included) to initially accept. To not penalize a student for late work can be a difficult policy to embrace. However, if a teacher truly believes that students should be graded on achievement, as I believe they should, these guidelines should be adhered to. This should not imply that attendance, behavior, punctuality, etc. are not important. These can always be *reported* as separate standards. However, they should not be included in a final grade that is supposed to reflect *academic achievement*.

Another commonality across the literature is that standards-referenced grading helps students by teaching what quality looks like. Scriffiny (2008) noted that quality is a very important concept in education and is a skill that must be learned. By focusing on achieving measurable standards, standards-referenced grading provides an opportunity for students to learn how to produce quality work samples – which is a skill that directly translates to the workplace. Criteria for performance must be defined in advance and students must be made aware of the criteria. When grades depend on clear standards that have been communicated and are understood by all stakeholders (students, parents, and teachers), student learning and success are encouraged (O'Connor, 2009).

If students are taught what quality work looks like, this knowledge can be then used to improve performance, and thus the student's grade (Clymer & Wiliam, 2007). This means that students must be given several opportunities to improve and show proficiency. If a grading system is truly based on what students know and can do, the focus must be on what the student knows at the *end* of the grading period. This causes students to learn at a deep level, rather than simply rely on rote memorization to pass a test and immediately forget the material (Clymer & Wiliam, 2007).

The idea of multiple opportunities for students to show proficiency gets back at the heart of standards-referenced grading. A hallmark of standards-referenced grading is that assessment can be used to communicate achievement, but it is also used by students and teachers as feedback (Reeves, 2011). When given multiple opportunities to show achievement, students can use their grades as feedback, and combined with the knowledge of what quality looks like, can improve their work to show proficiency. Life is full of second-chances, and the classroom should be no different (Wormeli, 2014). Students should be given multiple and varied opportunities to show achievement. Students learn at different rates and in different ways. When given feedback and multiple opportunities to show proficiency, students can achieve at higher levels (O'Connor, 2009).

Giving students multiple opportunities to show proficiency is useful to teachers, as well. When a standard is assessed multiple times, the teacher can use data to make decisions about instruction. Formative assessment is described by the Iowa Core as an assessment process that provides feedback to adjust teaching (Iowa Department of Education, 2012). Formative assessment is a practice that is not only accepted, but expected of all teachers in Iowa. Each assessment given should be used as evidence for students to demonstrate proficiency in one or more standards, but should also be used to make instructional decisions. When more information about student achievement is available, teachers are better informed to make instructional decisions (Scriffiny, 2008).

Summative assessments differ from formative assessments in that summative assessments are assessments *of* learning, while formative assessments are assessments *for* learning (Keeley, 2008). Summative assessments tend to be more formal, tend to be given at the end of instruction, and tend to be graded (Keeley, 2008). However, the key is that formative assessment (or a summative assessment that is used formatively) will provide information to the teacher to use for making instructional decisions, as well as activating, encouraging, and deepening student thinking (Keeley, 2008).

Grading System Within Standards-Referenced Grading

A characteristic of formative assessments is that that they are often not graded, but they are used to guide instruction. However, any assessment can be used as evidence to show proficiency for a standard. Test? Quiz? Lab report? Portfolio? Discussion? Opener? Homework? Lab? None of these is more important than the other in a standards-referenced grading system, it is simply all used as evidence. Should a short formative assessment be worth fewer points than a large summative assessment? This brings up another common characteristic of standards-referenced grading systems: the 4-point grading scale.

Proper implementation of a standards-referenced grading system requires a dramatic shift in how grades are determined. A 4-point scale is suggested by many experts (Marzano, 2010, O'Connor, 2011, Reeves, 2011). The basis of a 4-point grading scale is that every assessment is worth 4-points, and a student receives a 4, 3, 2, 1, or 0, depending on their level of proficiency. If necessary, a 20-40-60-80-100% scale is then used to determine a final grade. There are several reasons for utilizing a 4-point scale, but two stand out: mathematical accuracy and fairness.

One mathematical reason to use a 4-point scale is that a 100-point scale is simply not accurate (Reeves, 2004). If a student needs 60% to receive a passing grade, receiving 0% out of 100 on an assessment will hurt that student's grade more than a 100% will help. If 60% is necessary for a passing grade, there is also a distortion between grades and a 4-point GPA scale, which many schools use. To get around this, many schools have adopted a "50% minimum" policy on all assessments. Some stakeholders contend it "keeps hope alive" for students (Cox, 2011), while others often become discontent with a student receiving 50% on an assignment they did not complete. Reeves (2011) suggests it is a psychological necessity for teachers to have the option to give a zero on an assignment. A 4-point scale can solve both problems of mathematical inaccuracy and the psychological necessity of a zero. A student can receive a 0 on an assignment, but their grade is not impacted as much as a 0 on a 100-point scale.

When grades are determined by a specific rubric that has been communicated to students and parents, grades become fairer. Within the classroom, Reeves (2011) says that fairness means a student's performance determines their evaluation. It isn't difficult to find teachers of common courses grading identical topics or even identical assessments in different ways. Teachers of common courses must use the common assessments and common rubrics to determine grades. If not, students play the "teacher lottery;" a given student may receive a different grade on the same assessment, depending on how the teacher determines grades.

To make a fair grading system, the levels of proficiency that align with a 4, 3, 2, 1, or 0 must be clearly defined. If the levels are not defined, a 4-point scale turns into nothing but a 20-40-60-80-100% grading scale that will cause grade inflation. In the professional development experiences at my school, teachers often asked "if 20% is a passing grade, doesn't it make it easier to pass a class?" The answer is no; a 1 is defined as "beginning," and academic descriptors in a grading scale should describe the bare minimum to receive a passing grade. The key is a clear and rigorous definition of a 1 on the rubrics for each standard.

Definitions of 4, 3, 2, and 1 range from simple descriptors, such as "beginning, progressing, proficient, and exceptional," respectively, (Guskey, 2001) to very specific definitions:

- "An *A* means the student has completed proficient work on all course objectives and advanced work on some objectives.
- A *B* means the student has completed proficient work on all course objectives.
- A *C* means the student has completed proficient work on the most important objectives, although not on all objectives. The student can continue to the next course.
- A *D* means the student has completed proficient work on at least one-half of the course objectives but is missing some important objectives and is at significant risk of failing the next sequence in the course. The student should repeat the course if it is a prerequisite for another course.
- An *F* means the student has completed proficient work on fewer than one-half of the course objectives and cannot successfully complete the next course in the sequence" (Scriffiny, 2008).

The Des Moines Public Schools define 4, 3, 2, 1, as exceeding standard, meeting standard, developing toward standard, and insufficient progress, respectively. A score of 0 is defined as "no evidence of student understanding in submitted work," which is different from an M, which means that the assignment is missing (Des Moines Public Schools, 2014a). These definitions, along with "does not fulfill standard" for a score of 0, are used for the rubrics in this project. These definitions have changed in the past and will surely change in the future as standards-referenced grading is implemented by more teachers across the district (at this time, middle-schools and 9th grade courses in high schools are fully implementing, 10th grade courses will next year, 11th the year after, and so-on).

Any grading system will have imperfections, and there is no single correct way to calculate a grade. Should the mean, median, or mode be used to calculate a grade? Should emphasis in a final grade be given to more recent assignments? Should group grades be ignored when calculating a grade? Steps can be taken to make grades as fair as possible, however, across the literature, when a final grade must be determined, the bottom line is that teachers are must use *professional judgment* (O'Connor, 2011)!

When deciding on what physics knowledge to assess, the conceptual physics data team at my school struggled to find a balance between a large number of very specific objectives and a small number of objectives that cover large topics, but are difficult to assess. Should we have separate standards that state “student can describe the structure of an atom,” “student can determine the number of protons in a given element using the periodic table,” student can determine the number of neutrons in a given element using the periodic table,” etc.? We opted to have a standard that encompassed everything they should know about atoms; “Student can describe the structure of an atom and can explain how it relates to the periodic table and its role in static electricity.” We then ran into problems defining scores of 4, 3, 2, and 1. For example, we found that students could often show proficiency in what we perceived as more difficult skills (like determining the number of protons and neutrons in an element based on the periodic table) but struggled on what we thought to be basic “2-level skills,” such as describing the basic structure of an atom. What kind of grade should this student receive?

Sadler suggested avoiding standards that are too specific. Educators often tend to make learning objectives more and more specific with the goal of increasing objectivity of the grading process. However, as the objectives increase in specificity (and in number), they also become unmanageable (Sadler, 2005). Additionally, with more objectives comes an increased probability that each objective becomes isolated, and less opportunity for making connections within the content (Sadler, 2005).

For this project, I have chosen to use standards from the DMPS Conceptual Physics curriculum, which are based on the Iowa Core. The Next Generation Science Standards (NGSS) have been released and appear to be the future of science education in many states, but at this time, Iowa has not adopted the new standards. The first NGSS performance standard that would be included in the curriculum for this course wouldn't be until the second unit about causes of motion. Standard HS-PS2-1 expects students to "analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration" (NGSS Lead States, 2013). This shows that a dramatic shift in what is taught in this course will be required if the NGSS are adopted. This may be the future of what is taught in science classes in Iowa, but for this project, the DMPS and Iowa Core standards will be utilized.

Chapter 3: An Introductory Unit For 9th Grade Conceptual Physics

When writing a unit, one should begin with the big picture and ask "what do we want students to know and be able to do?" Our district Conceptual Physics curriculum team started with a big idea (a standard), broke each standard into clusters, and then divided each cluster into topics (if necessary). It was suggested to have no more than two topics per cluster, and no more than two clusters per standard. This was to keep each standard manageable.

This unit, entitled Forces and Interactions, has only one content standard: "Understand and apply knowledge of motions and forces." The standard is broken into two clusters, "motion" and "forces." The "motion" cluster has one topic, "describing motion." (Des Moines Public Schools, 2014b). Table 1 displays the content curriculum overview for Unit 1.

Table 1. DMPS Conceptual Physics Unit 1 Overview

Unit	Content Standards	Reporting Cluster(s)	Content Topics
Forces and Interactions (Semester 1)	Understand and apply knowledge of motions and forces.	Motion	Describing Motion
		Forces	Causes of Motion
			Matter Interactions

After identifying topics, the curriculum team created a grading scale for each topic using the definitions of 4, 3, 2, 1, 0, and missing (Des Moines Public Schools, 2014a) that are displayed in Table 2. These descriptors are used across all curricular areas.

When creating the grading scales, the curriculum team started by defining "level-three," which is considered proficient. After identifying desired student understandings and abilities, skills that are considered to be "level-two" were defined. Level-two skills are considered to be more basic than level-three: the level-two skills in the grading scale starts with "Students will recognize or recall." The vocabulary and basic knowledge is described in the level-two skills.

Levels 1 and 4 are not defined. Questions that show 4-level knowledge are put on district assessments, but they are not defined as more in depth skills, simply applications and in-depth inferences of 3-level skills. Students that have not shown sufficient progress toward level-two skills receive a 1. Table 3 contains the grading scales used for Unit 1.

Table 2. DMPS Academic Descriptors

Scale Score	Academic Descriptor
4	Exceeding Standard
3	Meeting Standard
2	Developing Toward Standard
1	Insufficient Progress
0	No evidence of student understanding in submitted work
M	Missing – student has not submitted evidence

After scores are given to assessments and a body of evidence is collected for a student, scores are translated into grades. A score of 3 is assigned an A, because the student has shown sufficient knowledge within a standard, while a score of 4 will show up on a grade report as A (honors), because the student has gone above-and-beyond. Each half-point below 3 will drop a student's score one letter grade, for example a 2.5 translates to a B, a score of 2 earns C, a 1.5 is a D, and 1 is an F.

It is worth noting that a student cannot get a passing grade without showing some level of understanding. They can't simply answer the easy questions on a test, make some lucky guesses on some multiple choice questions, and get 60% to pass an assessment. Students must show some level of proficiency to get even a 1.5 (which is considered the minimum grade to receive a D). This is a major issue that many teachers have with a 4-point scale: if a student only has to get a 1 (or in the case of DMPS, a 1.5), isn't it easier to pass a class (Reeves, 2004)? With well-defined standards and grading scales, this is not the case.

Table 3. Grading Scale for Describing Motion Cluster

Reporting Cluster: Motion	
Score	Knowledge
4	In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the target.
3	**Students demonstrate they have developed an understanding of:** • the conceptual and mathematical relationships between distance, speed, time, and acceleration **Students demonstrate they have the ability to:** • manipulate the formulas for velocity and acceleration to find an unknown • interpret distance vs. time and speed vs. time graphs
2	**Students will recognize or recall:** *Specific vocabulary such as:* • Distance, time, velocity, speed, acceleration *Basic knowledge such as:* • metric units of motion (meters, seconds, m/s, m/s2) • how to calculate velocity using v = d/t • how to calculate acceleration using a = (vf – vi)/t **Students demonstrate the ability to:** • create a distance vs. time and a speed vs. time graph
1	Student's performance reflects insufficient progress towards foundational skills and knowledge.

Once learning objectives are established and grading scales created, one can create lessons and write assessments. It took me about a year to realize that it is much easier to start with the scale and then write assessments rather than write assessments based on what I've taught, then write a scale for each assessment. Assessments can be found in the appendix D.

Before scoring assessments, our team comes together and collaboratively scores an anonymous sample of assessments. Each teacher (in addition to administrators, teacher coaches, and anybody else attending the team meeting) assigns a score for what they feel most accurately depicts the student's knowledge in relation to the grading rubric. There are often disagreements, which are necessary to discuss before actual grading. As the scoring process becomes more and more familiar, content area data teams find that the score discrepancies between teachers tend to grow smaller and smaller. The collaborative scoring process also assures that all teachers are on the same page before they score their assessments, so that students are not receiving a better grade because they have a teacher who is an easier grader.

When scoring an assessment, the grading scale dictates the score. Assessments begin with questions that are written to assess level-2 skills, then advance to level-3, and generally finish with a level-4 question. The question levels are usually not marked on student assessments ("Do I have to do the level-3 questions?" is a common question if they are marked), but for the purposes of this project, I placed a red bar that separates the level-2 and -3 questions on each assessment in Appendix D. Ideally, students that have level-2 skills will get only the level-2 questions correct, level-3 students will get all of the level-2 and -3 questions correct, etc. When this doesn't happen, which is more often than not, grading can become more complicated. Students sometimes show partial level-2 knowledge along with partial level-3 knowledge. What kind of score should they receive?

Our physics team has found that it's fair to allow a mistake or two on the level-2 questions before dropping a student to a grade of 1.5, which equates to a D. If they make too many mistakes and drop to a 1.5, we decided that it's also fair to bump the student back up to a 2 or higher if they show partial (or complete!) knowledge in the level-3 questions. With the exception of one or two mistakes, errors in either section will assure that the student does not receive a 3, which equates to an A.

While this sounds like a complicated process, practice, collaboration, and professional judgment make fair and accurate scoring the norm. The questions to always be mindful of: what does the student truly know? Where does that knowledge fall on the grading scale? What score most accurately depicts their knowledge of this physics topic?

A problem that our team encountered was that knowledge within a topic can often be a very different from other knowledge within the same topic. For example, in order to achieve a 3 in this unit, students must show knowledge about both speed and acceleration. This is problematic for grading because acceleration is a topic that students do not learn until end of the unit. Students need grades (read “feedback”) on the more basic topics, such as speed, before moving on to acceleration. For this reason, we decided to write separate assessments about speed and acceleration. There are two assessments about speed, one about acceleration, and one district assessment for the end of the unit about both. This fits with the district standard of a minimum of two pieces of evidence per topic. Ideally, a student’s most recent score was the highest, so we averaged the final speed and acceleration score for a final topic score. There is no need to include the previous grades, which become formative after more recent scores are obtained.

Of course, practice and theory are not always the same, and students sometimes have their scores on a topic drop from one assessment to the next. This is where teacher discretion is very important. If the majority of students are getting worse scores, there may be a rigor problem with one (or more) of the assessments. Sometimes, a student will get a worse score because they are having a bad day. Some would argue that once a student has achieved a score, their grade for that topic cannot go down (Wormeli, 2011). I have found that many teachers disagree, and that it shows a lack of knowledge if a score has dropped. If they know the material, they will do fine on an assessment. I find that if a student’s score has dropped, it’s fair to give a score somewhere in the middle of their two scores. If a student is having an off day, they can always retake the assessment. As stated, it is all up to teacher discretion.

In general, a class period includes at least one objective question (a question which students are expected to be able to answer by the end of the lesson), an opener (which may be an attempt to unlock prior knowledge, review from a previous lesson, or new information presented in a reading, as reading in all classes is an expectation in my building), possibly some direct instruction, and an inquiry-based investigation. Each lesson is carefully written with the question “how do students learn?” always in the back of my mind. Table 4 shows a rough outline of each lesson in the unit, which can be found in more detail in Appendix A.

Table 4. Summary of Lessons

Day 1: Measuring Length	After learning how to set up their notebook, students measure the length of various objects using everyday materials such as paperclips, including some un-standardized devices, such as their feet.
Day 2: Metric Units of Length	Students should have recognized the need for standardized units of measurement, so they measure the lengths of various objects using metric units.
Day 3: Graphing	Students are introduced to scientific graphing after measuring dimensions of their bodies. Carefully selected measurements, such as height and wingspan, introduce students to the idea of a meaningful slope.
Day 4: Measuring Time	The timers that are used in my classroom came with a suite of materials from CPO science. Students get their first encounter with the timer, including how to use it as a stopwatch and how to use a photogate.
Day 5: Speed	At this point, students have learned how to measure distance and time, so they now learn how to measure/calculate speed.
Day 6: More on Speed	Speed is a concept that cannot be understood in one lesson, so the students continue to practice measuring distance and time, then calculating speed. This activity differs because they calculate speed for a much smaller interval of time (through 1 photogate), which is assumed to be an instantaneous speed.
Day 7: Car on a Ramp	Students use their skills at calculating instantaneous speed to measure the speed of the car at a given point on a ramp. They change the incline of the ramp, which is their first tine to practice recognizing independent and dependent variables.
Day 8: Acceleration	Taking a rather large step, students now investigate changing speed. By calculating the instantaneous speed at the top and bottom of the ramp, as well as the time it took, they learn to calculate acceleration.
Day 9: More on Acceleration	World’s Fastest Drag Race is a video that is found online, students practice calculating the average acceleration of a car they select in the video. They receive more practice at calculating and understanding acceleration.
Day 10: Friction	The final lesson in this unit involves using a sled, which is identical to the car but has no wheels. Students recognize that even though the car slows down, they can still calculate the rate of acceleration, but find that it is a negative number.

Chapter 4: Reflection

My learning through researching, refining, and applying the ideas in this project has had a significant impact on student learning at the classroom and building level, as well as on the curriculum at a district level in the largest school district in Iowa. While my learning isn't complete, the project has deepened my understanding and put me in a position to help students.

At the classroom level, I have been able to improve my practice with standards-referenced grading. A teacher can read all of the books and articles they want, but to have a true understanding of standards-referenced grading and its role in the classroom, they have to try it out. It can be a long process, sometimes taking up to 5 years to feel like you're doing it right (Wormeli, 2014). After utilizing the grading system for nearly 3 years, I feel that I'm still learning, but my research has put my ahead of the game. My practice has made a significant, visible improvement.

At the building level, I've been able to lead the Conceptual Physics data team in using standards-referenced grading, including helping my team shift their mindset to standards-referenced grading, making grading scales (before the district-created scales were written), and writing and aligning assessments to standards. As a member of my school's leadership team, I have also been able to help our administration make decisions about standards-referenced grading, as well as help plan professional development to help our teachers.

At the district level, my knowledge of standards-referenced grading has helped me be a leader of the conceptual physics curriculum team. As one of the only members that has utilized standards-referenced grading, let alone read the literature, I helped the team create a quality document for the first year of implementation (the 2014-15 academic year). This document will be edited as we go, but the team has the conceptual physics teachers district-wide off to a good start.

As with any lessons that a teacher plans out, revisions are necessary. There is no such thing as a perfect lesson. As I teach these lessons (and any other lessons I teach), I constantly reflect on what can change to improve student learning. What I've written in this project was either new lessons or revised versions of lessons I've taught in the past, and these lessons will certainly be revised in the future. Even as I taught these lessons, I found that after adding in time for assessments, feedback, re-teaching, and more practice, it took closer to 20 school days to cover all of this material.

As stated, my knowledge of standards-referenced grading still has holes and I'm working toward improving my practice as I gain more experience. Whenever I struggle with a problem, whether it's about utilizing standards-referenced grading or how to better teach a lesson, I try to remember that the cognitive dissonance and frustration I'm experiencing are necessary to learning.

For my future development as a teacher, a major skill I wish to improve is the ability to differentiate. This is a skill that many teachers think they do well, but don't. With a shift to the mentality that grades are feedback and nothing else, it becomes easier to identify where a student excels and where they need to improve. Once students' skills are identified, the next step is to help them improve from where they are. Differentiation, both for high- and low-level students, becomes increasingly important in a standards-referenced classroom.

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Appendix A: Lesson Outlines

Unit 1, Day 1: Measuring Length

Objective Questions:

- Why are standardized units important?
- What is the standard unit of length used in physics?

Lesson Outline:

Because this is the first day of school, students are given their lab notebook and taught the daily routine. Students are expected to copy down the objective questions (so they can answer them at the end of class) and answer the opener questions. Today's opener is to get students thinking about exactly what science and physics are.

Because students often struggle with the differences between distance, time, and speed, it is important to begin with a chance to practice measuring them separately. This lesson (modified from the American Modeling Teachers Association materials (American Modeling Teachers Association, 2014) is intended to help students develop a model of length and distance. For years, students have measured using inches and centimeters, but they often lose sight of exactly what they are doing in measuring the length of an object. Students are purposely given small objects (paperclips), larger objects (PVC pipes), and objects of differing lengths (writing utensils and their feet). When students share their results on their whiteboard, hopefully they realize the importance of using a common unit of length, as well as the utility in being able to break that unit into smaller units for measuring smaller objects. By the end of this lab, students will hopefully be begging to use a meter stick.

Unit 1, Day 2: Metric Units of Length

Objective Question:

- How do I accurately measure length using the metric system?

Lesson Outline:

Students often enter my classroom often not knowing the difference between a yard and a meter, or even which side of the meter stick is metric. Many students need the introduction to the metric system, as well as practice using it. It is unfair to students to assume they know how to measure, when my experience tells me that many students have probably learned it in the past, but did not get prolonged practice, therefore have forgotten their measuring skills. The purpose of today's investigation is twofold: students will practice measuring using the metric system, and they will have data to learn basic graphing skills in the next day's lesson. Both of these skills will be used throughout the entire school year.

Some students will need help with the differences between meters and centimeters (it is not uncommon for them to believe they are 150 meters tall). While some students struggle with this idea throughout the entire year, it is important to start with good habits.

Unit 1, Day 3: Graphing

Objective Questions:

- How do I make a scientific graph? What is important to include?
- How do I calculate and analyze the slope of a graph?

Lesson Outline:

The purpose of this lesson is to teach students how to make a scientific graph. The opener is intended as a review about decimals, as many students struggle with this when they enter my classroom. Most graphs that students make will involve decimals, so it is important to keep in mind that many students struggle with them.

Using direct instruction, students are taught the important elements of a scientific graph and can follow along with the “How to Make the Best Graph Ever” handout. Responsibility is gradually released to students as students are shown how to make a graph then practice on their own using data from the previous lesson. Students are asked “what is the relationship between the spine-to-fingertip length and their wingspan for the students in this class?” When students make a graph with spine-to-fingertip on the x-axis and wingspan on the y-axis, they should find a slope of about 2. Students will likely need help with the slope analysis, especially with this being the first time. Students should be asked to analyze what the slope represents, although many will struggle with this being the first attempt.

For an extension on the lesson, students can graph other pieces of their data. How are the wingspan and student height related? What happens to the slope if you graph centimeters instead of meters? What if you graph meters on one axis and centimeters on the other?

Unit 1, Day 4: Measuring Time

Objective Question:

- How do I accurately measure time?

Lesson Outline:

Students are asked to fill out their opener on a notecard, which will be collected. These questions are designed to formatively assess if students have a basic understanding of decimals and converting between meters and centimeters. This is a formative assessment, thus is not graded, but can be used for both guiding instruction and a learning opportunity for students who still don’t understand the concept.

In the learning activity, students are introduced to the CPO lab equipment that our district has provided. Students tend to be engaged when they attempt to measure the smallest amount of time, which came from the investigation manual from CPO Science (Hsu, Physics: A First Course Investigations, 2005). For today, they only use the stopwatch feature of the timer, but in future lessons they will become familiar with the photogate, which measures time to the 10,000th of a second. Students also will practice averaging numbers, which is a skill that most can do, but will need some practice.

Unit 1, Day 5: Speed

Objective Question:

- In physics, what is speed?

Lesson Outline:

Now that students have developed concepts of distance and time, they can develop a concept of speed. Most of them already have some strong conceptions which may or may not be correct. While I am all for inquiry investigations, I do believe that reading has a time and a place in the science classroom. Students will not be able to read science text unless they practice. Students reading science text has been linked to higher science achievement (Diep, 2014). Today's opener asks students to read a short passage and answer questions about what they read.

The investigation in this lesson has students place photogates on a track and measure the distance and time that the car travels. Students will practice calculating speed and answer analysis questions aimed at developing concepts of speed, not necessarily a rote method of calculating it.

For homework, students will be given a set of practice problems (there are 2 forms). Students will be taught the "GUESS and Check" method, which is a 6 step method for solving physics word problems. GUESS and Check stands for identifying Givens, Unknowns, and an Equation, Set up, then Solve the problem. The last step is to Check that the answer is reasonable.

Unit 1, Day 6: More on Speed

Objective Question:

- How do I calculate the speed of a car?

Lesson Outline:

After practicing some basic speed calculations in the opener, students will identify units of distance, time, and speed. This is a reference that students can use when they are unsure of the differences in future lessons (which happens to the majority of them). The idea is to help students keep separate concepts of distance, time, and speed in their minds, because they often use the three terms synonymously.

Students will get more practice at measuring distance and time and calculating speed, but this investigation has a twist: they calculate an almost instantaneous speed of the car by using only one photogate. Students will also create a graph of their data (more practice) and use the data and graph to analyze if the distance that the car travels affects the speed.

Unit 1, Day 7: Car on a Ramp

Objective Questions:

- What happens to the speed of a car on an incline?
- What happens to the speed of a car if you increase the incline?

Lesson Outline:

In lieu of an opener, students receive their first assessment. The assessment covers all of the material thus far in the unit. Students have intentionally been given plenty of practice graphing and calculating speed, rather than receiving a formal assessment after their first attempt at learning the material. The assessment, as well as a modified version for students wanting to retake the assessment at a later date, can be found in Appendix D

Students will investigate the relationship between incline and the speed of a car. After plenty of practice at other skills, this lab is the beginning of a strong focus on identifying independent and dependent variables in an experiment. Students tend to struggle with this concept, and I have found that learning the skill once or twice will not suffice, it takes repetition (as with just about any skill). Students tend to have this skill mastered by the end of the semester, but it takes several labs before they get it.

The graph in this lab also introduces a new skill: making a prediction using the best fit line where there is missing data.

Unit 1, Day 8: Acceleration

Objective Questions:

- What is acceleration?
- How do I calculate acceleration?

Lesson Outline:

Now that students have developed an understanding of speed and been assessed on it, students will begin to develop a concept of acceleration. After reading an introduction to the topic, students will perform an investigation to observe what happens to the speed of a car as it moves down an incline.

After collecting data, students will calculate the speed and acceleration of the car, hopefully observing that the speed changes while the acceleration stays constant. Students will also make a speed vs. time graph, which is their first encounter with such a graph.

For homework, students will be given a short reading about acceleration and some practice problems.

Unit 1, Day 9: More on Acceleration

Objective Question:

- How are graphs used to describe motion?

Lesson Outline:

Having just learned about acceleration, today's lesson is intended to be for practice. The opener asks students to calculate the acceleration of a car in a drag race using the skills they learned in the previous class period. There is also a question that hints at the cause of acceleration and what can affect it, which will lead them in to the next topic. This opener can be used as a graded assessment.

After the opener, students will practice making graphs of motion using familiar stories (the 3 Little Pigs, Tortoise and the Hare). They have the option of making the graphs qualitatively or use numbers on their graphs. Again, this is intended to be practice for previously learned skills.

Unit 1, Day 10: Friction

Objective Question:

- How does friction affect the acceleration of an object?

Lesson Outline:

This is the final lesson that will be used as practice for the acceleration concept before this topic (describing motion) comes to a conclusion and the class moves to the next topic (causes of motion). Students will get more practice with acceleration, this time comparing the car they have been using to a sled (same thing without wheels). This activity was specifically designed to help students recognize that speed and acceleration are not the same thing, as they will observe that the car goes faster but has less acceleration as it moves along the track.

Appendix B: Daily Slides

Unit 1, Day 1: Measuring Length

Unit 1, Day 1: Measuring Length

- Objective Questions (Copy, but don't answer)
  1. Why are standardized units important?
  2. What is the standard unit of length used in physics?
- Opener (answer)
  - Set up your notebook.
  1. To you, what is science?
  2. To you, what is physics?

Length Measurement Lab

- Copy the data table into your notebook.
- Use the measuring materials in the first column to measure the different objects.

Measuring Device	Your Height	Paperclip	Pencil	Foot	Your choice
Paper Clip					
Pencil					
Foot					
PVC Pipe					

Sharing Data

- Copy your data on to a white board and display for the class to see.
- In your notebook, identify some similarities and differences between your data and other groups.

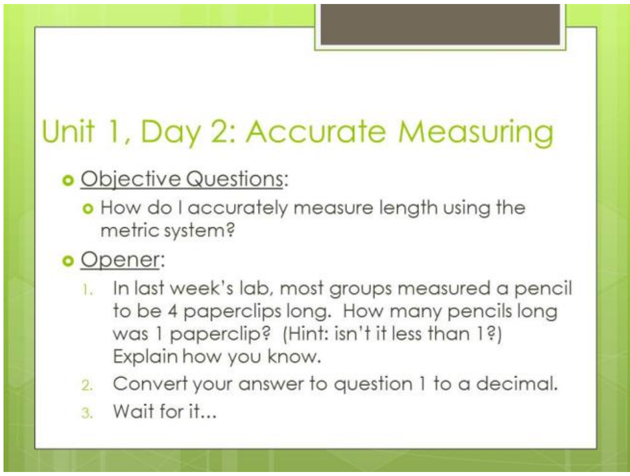
Analysis Questions

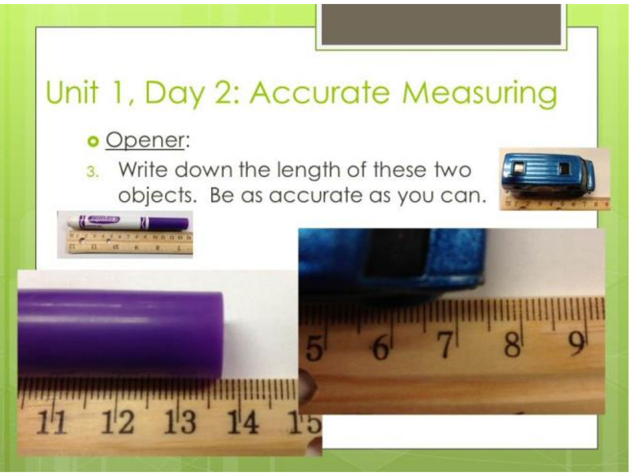
- Answer these questions in complete sentences your notebook:

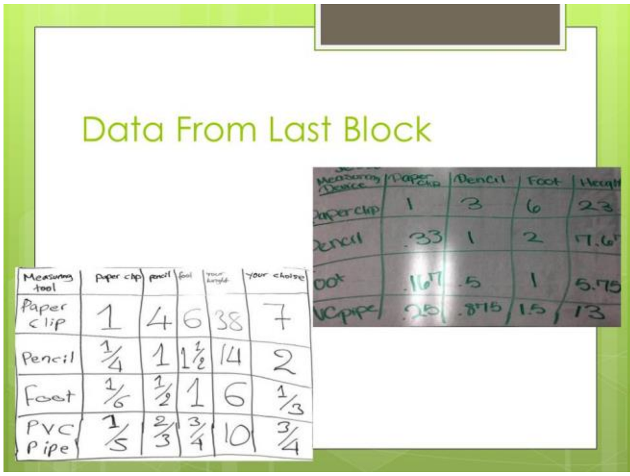
1. Why were there differences in data if groups were measuring the same objects with the same measuring devices?
2. How did you deal with measurements that weren't a whole number? Did it work out?
3. Why was it inconvenient to measure small objects with large measuring devices (like the PVC pipe)? Can you think of an example of when this happens in the real world?
4. Suppose the door was exactly 15 pencils tall. How can you figure out how many paperclips tall it is without measuring it?

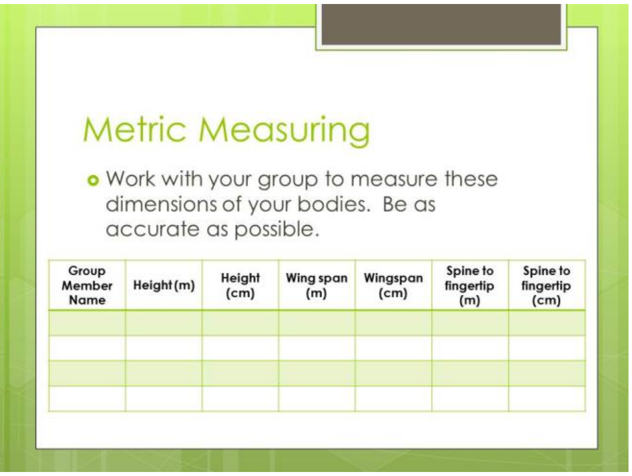
- Don't forget to answer the objective questions for the day!

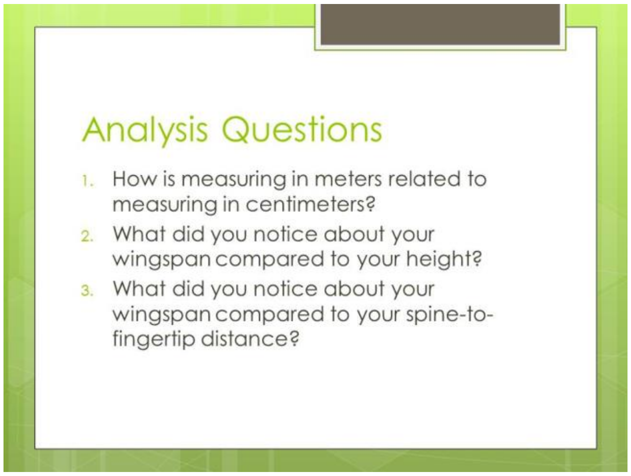
Unit 1, Day 2: Metric Units of Length











Unit 1, Day 3: Graphing

Unit 1, Day 3: Graphing

- Objective Questions (write them down!)
  - How do I make a scientific graph? (What is important to include?)
  - How do I calculate and analyze the slope of a graph?
- Opener Questions (answer them!)
  1. Use a ruler to measure the distance between two blue lines in your notebook. The metric system is your friend.
  2. Put these numbers in order from smallest to largest:
     0.757 0.5 0.75 5 0.7579 0.05
  3. What is the average of the numbers in question 2?
  4. Compare these numbers:
     0.05 .05 .050

Graphing

- What is the relationship between the spine-to-fingertip length and their wingspan?
- Make a spine-to-fingertip vs. wingspan graph of your data from last block.

1. Calculate the slope of your graph.
2. What does the slope represent?

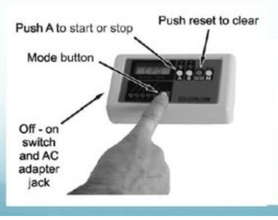
- Make a height vs. wingspan graph of your data from last block.

3. Calculate the slope of your graph.
4. What does the slope represent?

Unit 1, Day 4: Measuring Time

Timer Lab

- With your group, figure out how to use the CPO timer as a stopwatch.
  - How do you start the timer?
  - How do you stop the timer?
  - How do you reset the timer?



Unit 1, Day 4: Measuring Time

- Objective Questions:
  - How do I accurately measure time?
- Opener Questions **(ON THE NOTECARD!)**:
  1. Measure the length and the width of the notecard using the metric system and write them on the notecard. Use complete sentences, of course.
  2. Melissa's height is 161 centimeters. How many meters tall is she?
  3. Anna's fingernail is 1 centimeter long. How many meters long is her fingernail?
  4. Put the following numbers in order from smallest to largest:

  .01 0.10 1.0 .11 .111 0

Timer Lab

- Copy the data table into your notebook and record the times.
- Test to see who in your group has the fastest fingers. Who can measure the smallest amount of time? Each group member gets 3 trials.

Name	Trial 1 Time (s)	Trial 2 Time (s)	Trial 3 Time (s)	Average Time (s)
			Team average:	

- Calculate the average time and record it in the last column of your table.

Analysis Questions

1. Describe how you got the average time for your group.
2. If your teacher is added to your group, would the average go up or down? Your teacher's fastest time is 0.08 seconds.
3. Calculate what the average would be with your teacher's time. Were you right in number 2?
4. What is time?

- Answer the objective questions for the day!

Unit 1, Day 5: Speed

Unit 1, Day 5: Speed

Objective Question

In physics, what is speed?

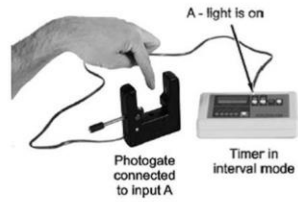
Opener

- Read pages 17 and 18 in the textbook, and answer these questions:

1. In physics, what does speed mean?
2. What exactly does it mean when we say a bicycle travels 3 m/s?
3. List three examples of units used to measure speed.
4. What do all units of speed have in common?

Using the Photogates

- Glue the data table into your notebook
- Run your tests and fill out the data table!



Calculating Speed with 2 Photogates

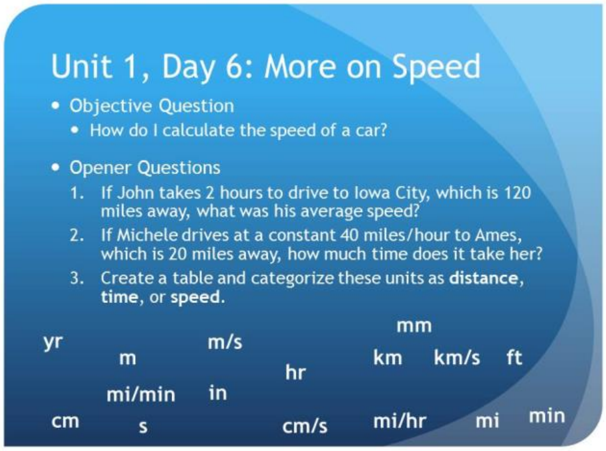
Distance Between Photogates (cm)	Trial 1: Time from A to B (s)	Trial 2: Time from A to B (s)	Avg. Time from A to B (s)	Speed of car (cm/s)
20				
30				
40				
50				
60				

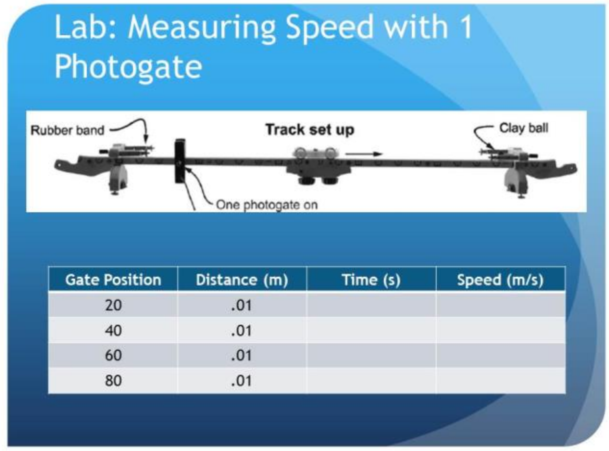
Analysis Questions

1. If the photogates are farther apart, what happens to the ***time*** for the car to get from A to B? *(Does it increase, decrease, or stay the same?)*
2. If the photogates are farther apart, what happens to the ***speed*** of the car between A and B? *(Does it increase, decrease, or stay the same?)*
3. How do you calculate the speed of the car from A to B?

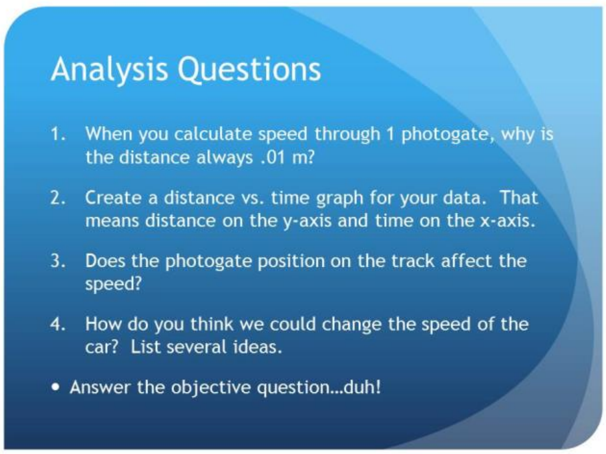
Answer today's objective question!

Unit 1, Day 6: More on Speed





Gate Position	Distance (m)	Time (s)	Speed (m/s)
20	.01		
40	.01		
60	.01		
80	.01		



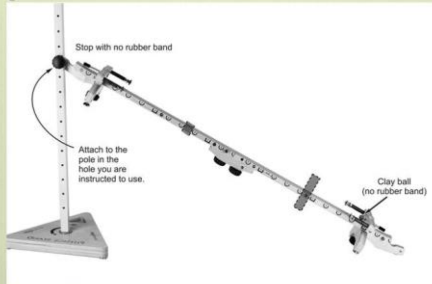
Unit 1, Day 7: Car on a Ramp

Unit 1, Day 7: Car on a Ramp

- Objective Questions:
  - What happens to the speed of a car on an incline?
  - What happens to the speed of a car if you increase the incline?
- Opener:
  - Speed assessment!

Car on a Ramp Lab

- Today we'll begin using the stands to create ramps with our tracks:



Car on a Ramp Lab

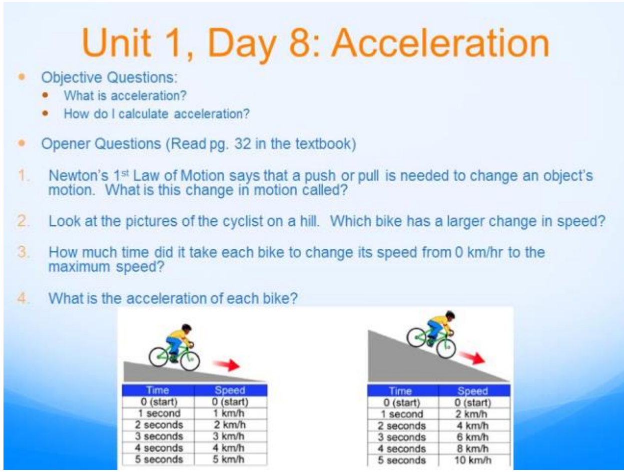
- Copy the data table:

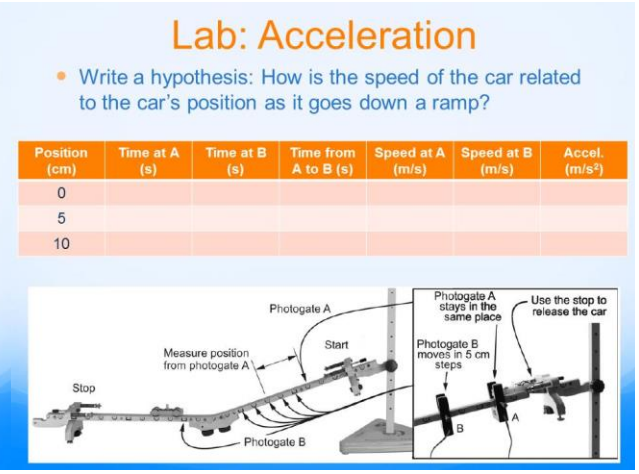
Hole #	Time (s)	Speed (m/s)
2		
5		
8		
14		
17		

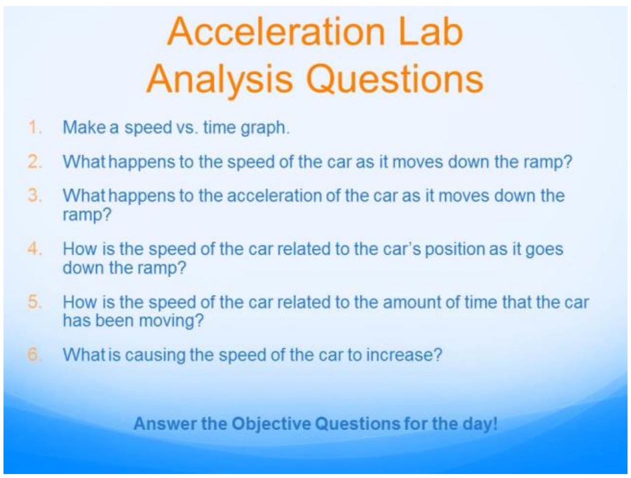
Car on a Ramp Lab Analysis Questions

1. What is the independent variable? (What did you control in the experiment?)
2. What is the dependent variable? (What was affected by the independent variable?)
3. Create a graph of speed vs. ramp height.
4. What is the relationship between ramp height and speed.
   Ex. As ramp height increases, speed ____________.
   (increases/decreases/stays the same)
5. Using your graph, predict what the speed would be at hole #12.
6. Use the speed and a known distance (.01 m) to calculate the time at hole #12.
7. Try it out! What was the actual time? If there is a difference, what caused it?

Unit 1, Day 8: Acceleration







Unit 1, Day 9: More on Acceleration

Unit 1, Day 9: More on Acceleration

- Objective Questions
  - How are graphs used to describe motion?
- Opener
  1. World's Fastest Drag Race: Pick a car from the line up and write it on your notecard.

World's Greatest Drag Race

- Pick a car from the line up of the World's Greatest Drag Race and write it on your notecard:
  - BMW 1-Series M, 335 horsepower (hp)
  - Ford Mustang Boss 302 Laguna Seca, 444 hp
  - Porsche 911 GT3 RS, 450 hp
  - Chevrolet Corvette Z06/Z07, 505 hp
  - Ferrari 458 Italia, 557 hp
  - Nissan GT-R, 530 hp
  - Audi R8 GT, 560 hp
  - Mercedes-Benz SLS AMG, 563 hp
  - Lexus LFA, 552 hp
  - Porsche Cayman R, 330 hp
  - Lotus Evora S, 345 hp

World's Greatest Drag Race

Car	Horsepower (hp)	Time (s)	Speed (mph)
BMW 1-Series M	335	12.8	110.2
Ford Mustang Boss	444	12.4	115
Porsche 911 GT3	450	11.9	120.7
Chevrolet Corvette	505	11.9	122.5
Ferrari 458 Italia	557	11.3	125.6
Nissan GT-R	530	11.2	121.8
Audi R8 GT	560	11.5	125.1
Mercedes-Benz SLS AMG	563	11.7	124.1
Lexus LFA	552	11.9	123.7
Porsche Cayman R	330	12.7	111
Lotus Evora S	345	12.9	109.9

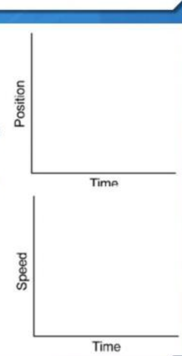
World's Greatest Drag Race

Answer these questions on your notecard:

1. Calculate the acceleration for your car.
2. Which car took the least time to reach the finish time?
3. Which car was going the fastest when it crossed the finish line?
4. Based on the data, which car won the race?
5. Why didn't the car with the greatest horsepower win?

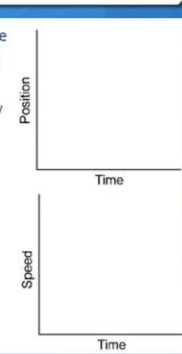
Graphs of Motion

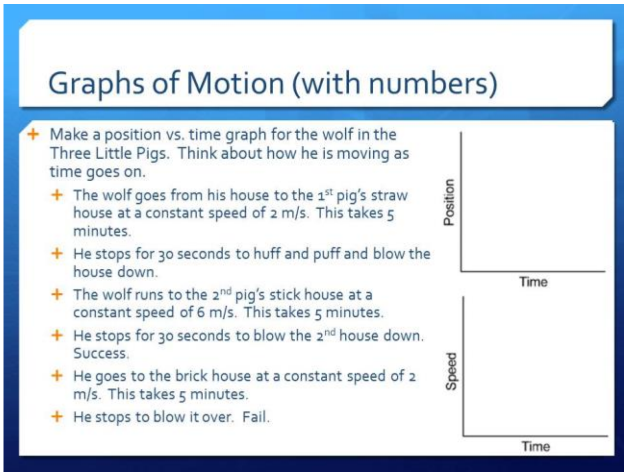
- Make motion graphs of the tortoise and the hare. That means 4 graphs: a position vs. time and a speed vs. time graph for the tortoise, and same for the hare.
  - The hare accelerates to a fast speed at the start of the race.
  - The tortoise has a slow, constant speed the entire race.
  - After some amount of time, the hare gets all cocky and takes a nap for a long time.
  - The hare wakes up to realize that he is losing and races to the finish line at top speed.
  - The tortoise gets to the finish line just before the hare.

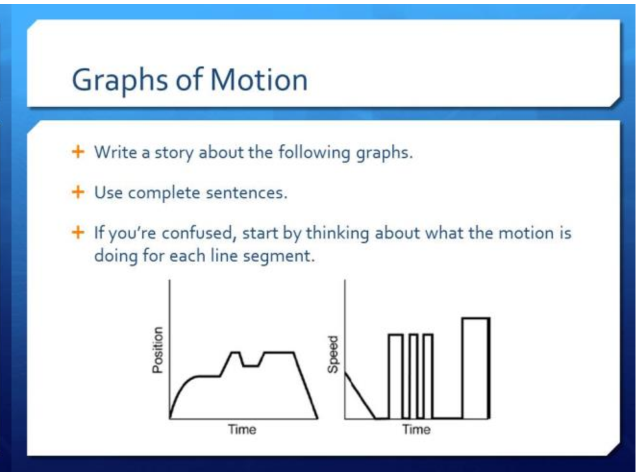


Graphs of Motion (without numbers)

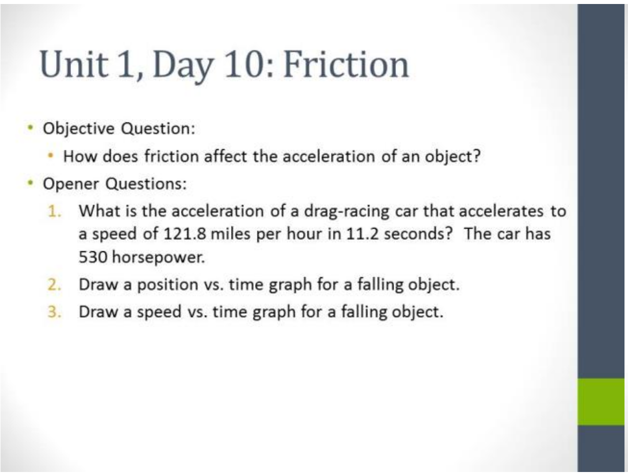
- Make a position vs. time graph for the wolf in the Three Little Pigs. Think about how he is moving as time goes on.
  - The wolf goes from his house to the 1st pig's straw house at a constant speed.
  - He stops to huff and puff and blow the house down.
  - The wolf goes to the 2nd pig's stick house at a constant speed.
  - He stops to blow the 2nd house down. Success.
  - He goes to the brick house at a constant speed.
  - He stops to blow it over. Fail.

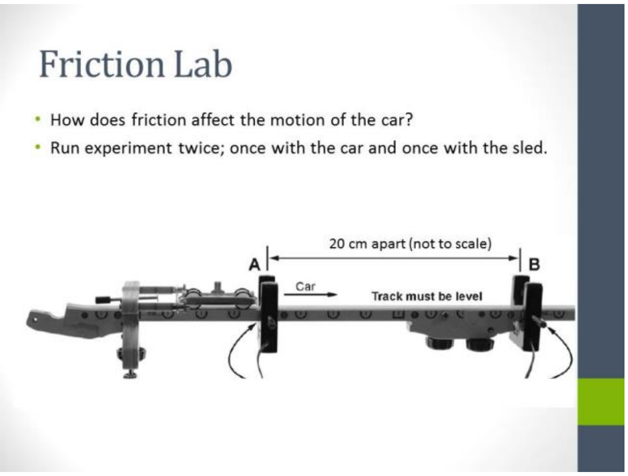


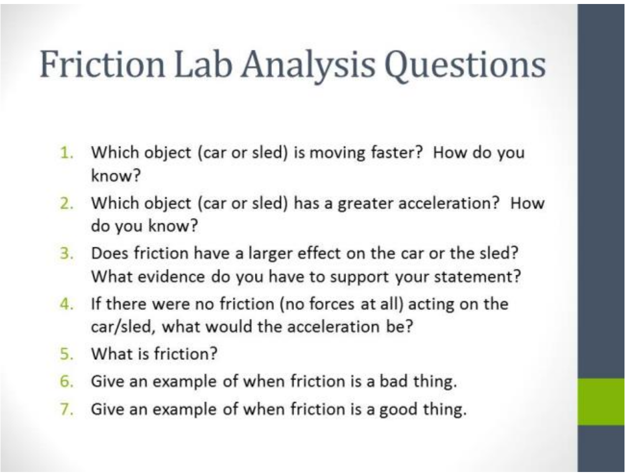

Graphs of Motion (with numbers)
Make a position vs. time graph for the wolf in the Three Little Pigs. Think about how he is moving as time goes on.
The wolf goes from his house to the 1st pig's straw house at a constant speed of 2 m/s. This takes 5 minutes.
He stops for 30 seconds to huff and puff and blow the house down.
The wolf runs to the 2nd pig's stick house at a constant speed of 6 m/s. This takes 5 minutes.
He stops for 30 seconds to blow the 2nd house down. Success.
He goes to the brick house at a constant speed of 2 m/s. This takes 5 minutes.
He stops to blow it over. Fail.
Position
Time
Speed
Time


Graphs of Motion
Write a story about the following graphs.
Use complete sentences.
If you're confused, start by thinking about what the motion is doing for each line segment.
Position
Time
Speed
Time

Unit 1, Day 10: Friction







Appendix C: Student Data Tables and Learning Activities

Unit 1, Day 3: Graphing

How to Make the Best Graph Ever

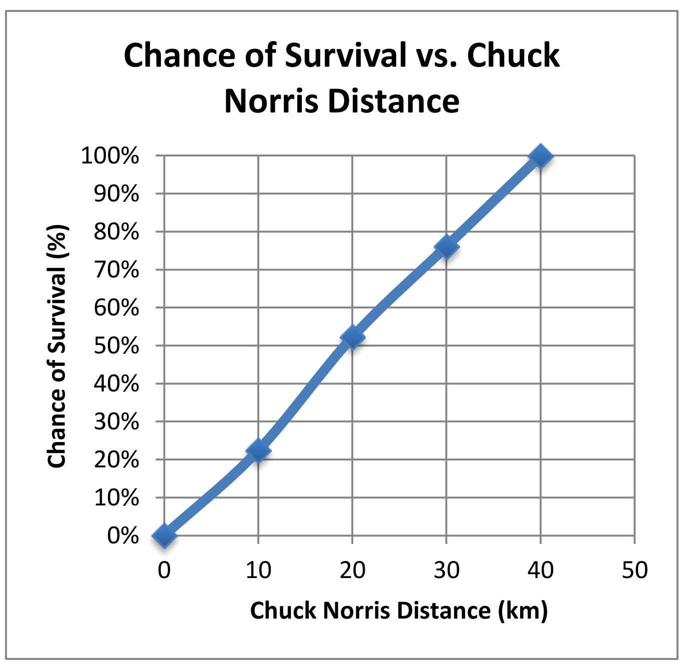
The following are required on every graph:

- ✓ A title
  - o It should be "dependent vs. independent"
- ✓ Labels on each axis
  - o The independent variable goes on the x-axis
  - o The dependent variable goes on the y-axis
- ✓ Units on each axis
  - o What unit are you using to measure?
- ✓ A scale
  - o Start at 0 and count by the same amount for each line on the graph
  - o Make the graph take up at least half of the graph paper.
- ✓ Data
  - o Make sure your data points are carefully plotted.
- ✓ Line of Best Fit
  - o A line of best fit shows the pattern in the data, but isn't necessarily connecting the dots.

Example: What happens to your chances of survival when Chuck Norris gets anywhere near you?

Data:

Chuck Norris Distance (km)	Chance of Survival (%)
0	0%
10	22.4%
20	52.2%
30	76.1%
40	99.9%



Unit 1, Day 4: Measuring Time

Timer Lab				
Light A	Light B	How do you START the timer?	How do you STOP the timer?	What time interval does the timer measure?
On	Off			
Off	On			
On	On			
Off	Off			

Unit 1, Day 5: Speed

Solving Velocity Problems

G:

U:

E:

S:

S:

and CHECK!

1. Calculate the average velocity of a train that travels 860 km in 9 hours.
2. How long will it take Beth to walk home from school if she can walk an average velocity of 6.6 km/hr and lives 4 km away from school?
3. If a fish can swim at a constant velocity of 2 m/sec, how far can it swim in 3 minutes?
4. Cory can jog at an average velocity of 9 km/hr. How long will it take him to jog 13 km?
5. Calculate the average velocity of a snail if it travels 125 cm in 73 seconds.
6. How far will a rabbit travel if it runs for 2 minutes at a constant velocity of 6 m/sec?

Solving Velocity Problems

G:

U:

E:

S:

S:

and CHECK!

1. Calculate the average velocity of a train that travels 860 km in 9 hours.
2. How long will it take Beth to walk home from school if she can walk an average velocity of 6.6 km/hr and lives 4 km away from school?
3. If a fish can swim at a constant velocity of 2 m/sec, how far can it swim in 3 minutes?
4. How long will it take a moose to walk 12 km, if it can walk at an average velocity of 4 km/hr?
5. Calculate the average velocity of a butterfly if it travels 120 m in 20 seconds.
6. How far will a fox travel if it runs at a constant velocity of 12 m/sec for 2 minutes?

Unit 1, Day 8: Acceleration

Acceleration Lab						
Position (cm)	Time at A (s)	Time at B (s)	Time from A to B (s)	Velocity at A (m/s)	Velocity at B (m/s)	Acceleration (m/s^2)
How to Calculate						
0						
5						
10						
15						
20						
25						

Acceleration Problems

Acceleration is the rate of change in the velocity of an object. That means an acceleration can be a change in *speed or direction*. A positive value for acceleration means an object is speeding up; a negative value means that the object is slowing down. This is called deceleration, but it is still a change in speed so it is still acceleration.

The formula for acceleration is as follows:

$$a = \frac{v_2 - v_1}{t}$$

where a is the acceleration, v_1 is the starting velocity, v_2 is the final velocity, and t is the change in time.

The unit for acceleration will always be a unit of speed per unit of time. For example, an acceleration 1 m/s/s means that an object accelerated by 1 m/s each second. After 1 second, it has a speed of 1 m/s, after 2 seconds, 2 m/s, and so on.

Example: A biker accelerates from a speed of 0 m/s to 10 m/s in 5 seconds. What is the biker's acceleration?

$$a = \frac{10m/s - 0m/s}{5s} = \frac{10m/s}{5s} = 2m/s/s$$

Yes or No: Which of the following objects are accelerating?

______ A car stops at a stop sign, then goes in a straight line.

______ A car stops at a stop sign, then goes and turns right.

______ A car uses cruise control to go in a straight line at a constant 65 miles/hour.

______ A car turns a corner at a constant 10 miles/hour.

______ A car slams on the brakes and comes to a stop.

Acceleration Problems

1. A skater increases her velocity from 2.0 m/s to 10.0 m/s in 3 seconds. What is the acceleration of the skater?

2. While traveling along the highway, a driver slows from 24 m/s to 15 m/s. This takes 12 seconds. What is the car's acceleration?

3. A cheetah, which is the fastest land mammal, can accelerate from 0 mi/hr to 70 mi/hr in 3 seconds. What is the acceleration of a cheetah?

4. The "0 to 60" test is often used to measure a car's acceleration. A Lamborghini Diablo can go from 0 km/hr to 99.2 km/hr in 4 seconds. What is the car's acceleration?

5. A car traveling at a speed of 30 m/s encounters an emergency and comes to a complete stop by slamming on the brakes. How much time will it take for the car to stop if its rate of acceleration is -4 m/s/s?

Appendix D: Assessments

CFA: SPEED
SHOW ALL WORK AND INCLUDE UNITS ON ALL ANSWERS!!

Shannon did an experiment with our cars and tracks. She used two photogates and tried to find out how the distance traveled affected the speed of the car.

1. Calculate the speed of the car for each of the distances. Write them in the data table below.

Distance Between Photogates (m)	Time between A & B (s)	Speed of Car (??)
.10	0.0606	
.20	0.1235	
.30	0.1887	
.40	0.2564	

What is the unit for the speeds calculated in the table above? (What should be written in the spot that says ??)

What happens to the speed of the car as it has a larger distance to travel? (Does the speed increase, decrease, or stay the same?) How do you know?

2. Lady Gaga is running late for the Grammys. The show is 20 miles away and she only has half an hour (0.5 hours) to get there. How fast does she need to go to get there on time? Show work and include units!

G

U

E

S

S

3. A student crabwalks a distance of 10 m. Her partners time her and say it took 12.05 seconds. What is the student's average speed?

G

U

E

S

S

4. Mr. Chai is driving to Iowa City to watch the Iowa Hawkeye football game. If it takes him 1.75 hours to drive there at an average speed of 102 km/hr, how far is Iowa City?

G

U

E

S

S

5. A student calculates her speed while hopping on one foot to be 2.45m/s. If it takes 6.48 s, how far did she go?

G

U

E

S

S

6. Starlord from Guardians of the Galaxy flies his spaceship a distance of 1,074 km. If he was going 642 km/hr, how much time does it take to get there?

G

U

E

S

S

7. You're running late for class and want to get there because you have learning to do! School is 2,583 meters away and you know you can run at 8 m/s. How much time will it take you to get to school?

G

U

E

S

S

8. Two swimmers are having a race. Anna completes the race in 20 seconds fewer than John. How do their average speeds compare?

9. A student launches a car down a track a distance of 80 cm and finds that it takes .4309 s. He then measures the speed through 1 photogate at the very beginning to be .0046 seconds. Was the instantaneous or the average speed higher?

CFA: SPEED 2

SHOW ALL WORK AND INCLUDE UNITS ON ALL ANSWERS!!

1. The cheetah, the fastest of land animals, can run a distance of 274 m in 8.65 s at its top speed. What is the cheetah's top speed?

G
U
E
S
S

2. A runner makes one lap around a 400 m track in a time of 52.0 s. What was the runner's average speed?

G
U
E
S
S

---

3. A baseball is pitched with a speed of 35.0 m/s. How much time does it take does it take the ball to travel 18.4 m from the pitcher's mound to home plate?

G
U
E
S
S

4. Polar bears are extremely good swimmers and can swim for 10 hours without resting. If a polar bear swims with an average speed of 2.6 mi/hr, how far will it have traveled after 10 hours?

G
U
E
S
S

5. The typical snail doesn't cover very much ground even when it is moving at its maximum speed, which is 0.005 m/min. How far will a snail travel if it moves at its top speed for 45 minutes?

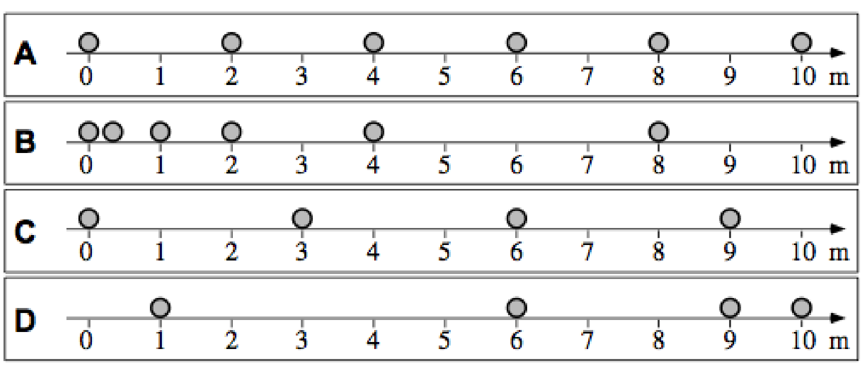
G
U
E
S
S

6. A bullet is shot from a rifle with a speed of 720 m/s. What time is required for the bullet to strike a target 3240 m away?

G
U
E
S
S

7. Mr. Sonntag finishes a race 42 seconds before Mr. Chai. What do we know about the average speed of Sonntag compared to Chai? Explain.

8. In each case a sphere is moving from left to right. A picture is taken each second, and the location of the sphere is recorded. Which sphere is moving the fastest after 3 seconds? Explain how you know. Calculate the speed of that sphere (after 3 seconds).



(Hieggelke, Maloney, Kanim, & O'Kuma, 2015)

CFA: ACCELERATION
SHOW ALL WORK AND INCLUDE UNITS ON ALL ANSWERS!!

1. A basketball is dropped from rest off of a building. It falls for 2.0 s, and reaches a speed of 19.6 m/s the instant before it hits the ground. What is its acceleration (ignore air resistance)?

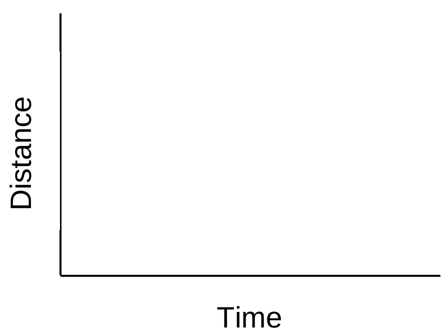
2. A bus is traveling at 50 mi/hr and slows to a speed of 15 mi/hr. What is the acceleration of the car if it takes 9 seconds to change its speed?

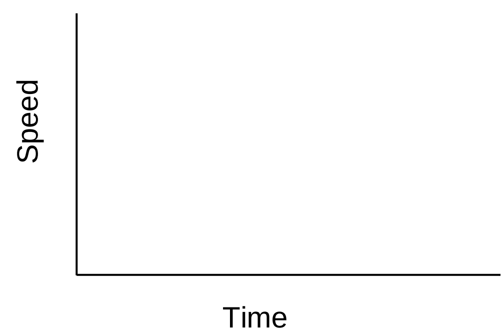
3. Explain what it means for an object to accelerate at a rate of 4.2 mi/hr/s?

4. Is it possible to have no speed and a large acceleration? Justify your answer.

---

5. A car is at rest waiting at a light. When the light turns green, it slowly accelerates to its top speed. The driver sees a ball bounce into the road and slams on the brakes, coming to a complete stop. On the axes below, sketch a distance vs. time and a speed vs. time graph.





6. A falling object accelerates at a rate of 9.8 m/s^2. If it falls from rest, what will be its speed after 1.8 seconds? (Ignore air resistance).

7. If a car accelerates at 1.5 m/s^2, how much time will it take to get from a speed of 15 m/s to 28 m/s?

8. Isaac and Albert are riding bikes down a hill when they come to a disagreement.

    Isaac says “when riding down a hill, even though I’m gaining speed, it will take the same amount of time to get to the bottom as if I were not gaining speed, because it’s the same distance from the top to the bottom of the hill.”

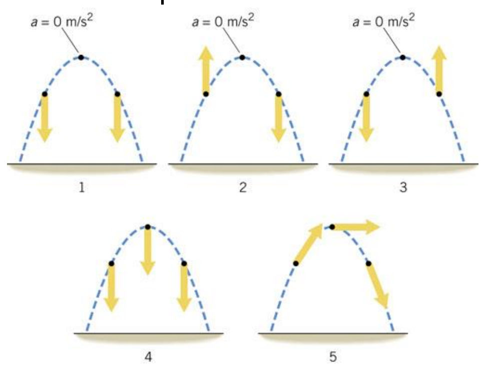
    Albert says “I disagree. We would travel the same distance if we were not accelerating, but it will take me more time. If I accelerate, I will have a higher speed at the bottom.”

    Identify one correct and one incorrect statement from each student. If a student has no correct or no incorrect statements, you can write “none” in that box.

Student	Correct Statement	Incorrect Statement
Isaac		
Albert		

Level 4

Each drawing shows the path of an object that is thrown upwards into the air and allowed to fall to the ground. The arrows represent the acceleration of the object at 3 different points on the path of the object: on the way up, at the top, and on the way down. Which of the following shows the correct arrows that represent the acceleration of the object?



(Cutnell & Johnson, 2009)

Justify your answer:

District Assessment
Conceptual Physics
Cluster: **Forces and Interactions**
Topic: **Describing Motion**
Semester: **Fall**

Level 2

9. Mike runs 400 m in 57 seconds. What is his average speed?

    A. 0.14 m/s
    B. 7 m/s
    C. 457 m/s
    D. 22,800 m/s

10. Kim runs the same distance as Mike, but does it in less time. Was her speed higher or lower than Mike's?

    A. Kim has a higher speed, because her time is larger.
    B. Kim has a higher speed, because her time is smaller.
    C. Kim has a lower speed, because her time is larger.
    D. Kim has a lower speed, because her time is smaller.

11. Howard drives a distance of 210 km in 2.5 hours. What is his average speed?

    A. 0.01 km/hr
    B. 8.4 km/hr
    C. 84 km/hr
    D. 525 km/hr

12. John swims 1,500 m in 28 minutes and 30 seconds. What is his average speed?

    A. 0.88 m/s
    B. 50.0 m/s
    C. 52.6 m/s
    D. 53.0 m/s

13. What does it mean for an object to accelerate at a rate of 4 km/hr/s?

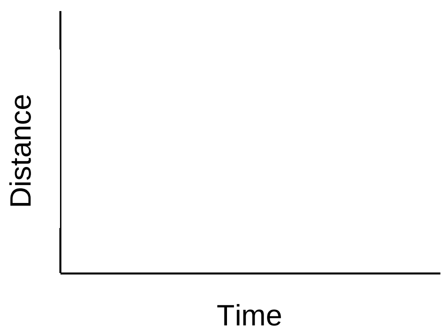
    ____
    ____
    ____
    ____
    ____
    ____

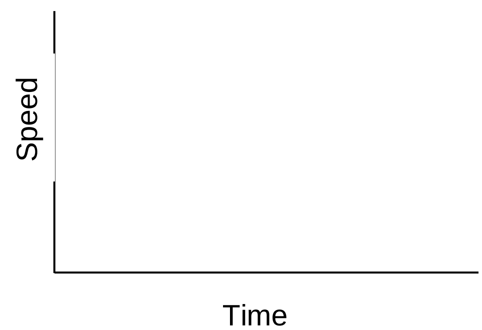
14. A basketball is dropped from rest off of a building. It falls for 1.5 s, and reaches a speed of 14.7 m/s the instant before it hits the ground. What is its acceleration (ignore air resistance)?

    A. $0.1\ m/s^2$
    B. $9.8\ m/s^2$
    C. $16.2\ m/s^2$
    D. $22\ m/s^2$

15. A car is traveling at 40 km/hr and slows to a speed of 15 km/hr. What is the acceleration of the car if it takes 6 seconds to change its speed? You must include a correct unit and sign for a correct answer.

16. A football player at rest catches a ball. He quickly accelerates to a higher speed, and then continues at a constant speed. He stops running when he scores a touchdown. On the axes below, sketch a distance vs. time and a speed vs. time graph.





<u>Level 3 Questions (all answers must show work and include units)</u>

17. Doug rides his motorcycle at an average velocity of 42 km/hr for 3.6 hours. What is the distance he traveled?

18. On a long trip across Canada, you begin to wonder “are we there yet?” You are traveling at a speed of 110 km/hr. You see a sign that shows your destination is 200 km away. How much time will it take to reach your destination?

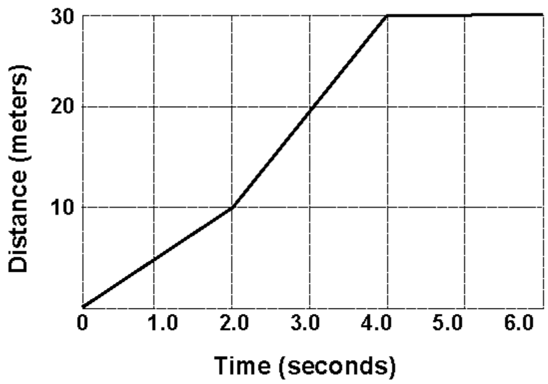
19. If Anna is running at a speed of 6 m/s, how much time will it take her to go 400 m?

20. How far did Anna (in the question above) travel if she runs at 6 m/s for 5 minutes?

21. A falling object accelerates at a rate of 9.8 m/s^2. If it falls from rest, what will be its speed after 3 seconds? Neglect air resistance.

22. If a car accelerates at 1.3 m/s^2, how much time will it take to get from a speed of 20 m/s to 30 m/s?

Use the graph below to answer questions 15 and 16.



23. What is the velocity of the object during the time interval between t = 2 s and t = 4 s?

24. Describe how the speed of the object at t = 1s compares to the speed of the object t = 3s? Justify your answer.

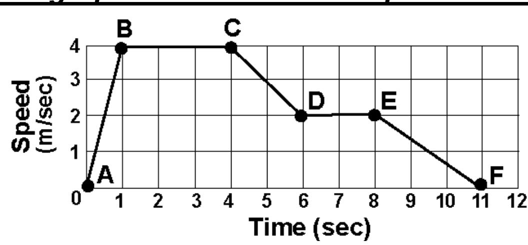
____

____

____

____

Use the graph below to answer questions 17 and 18.



25.

17. Between which two points on the graph is the car speeding up? Justify your answer.

18. According to the graph above, how much total time did the car spend moving at a constant speed? Justify your answer.

19. You wake up late for school but still want to make it on time. To make up for lost time, <u>should the following factors increase, decrease or stay the same?</u>

Factor	Increase, Decrease, or Stay the Same?	Justification for your answer
Distance		
Time		
Speed		

20. How is it possible to have a high speed and no acceleration? Justify your answer.

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Level 4

21. A 737 airplane can accelerate at a rate of 3.33 m/s^2. According to runway procedures, the plane has to start from rest before taking off. It takes 25 seconds for the airplane to reach a final velocity fast enough for lift off. The runway is 850m long.

    Will this airplane be able to take off from this runway? Justify your answer.

Show your work:

Justify your answer:

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