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IMPROVING INSTRUCTION OF MOTION AND ENERGY THROUGH A CONSTRUCTIVIST APPROACH AND TECHNOLOGY INTEGRATION

By

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ABSTRACT

IMPROVING INSTRUCTION OF MOTION AND ENERGY THROUGH A CONSTRUCTIVIST APPROACH AND TECHNOLOGY INTEGRATION

By

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This study focuses on developing meaningful learning of motion and energy in ninth grade Physical Science classes through a constructivist approach and technology integration. Constructivist strategies empower students to build new knowledge on what they already understand. LEGO Mindstorms and Texas Instruments TI-83 calculators/CBL sensors help implement constructivist learning.

Pre and post test data show large gains in student knowledge of motion and energy. Students had higher achievement on performance-based as opposed to written or mathematical/calculations-based activities. Students preferred the more student-centered activities. Students found technology integration captivating. Students found the unit challenging but engaging. The study suggests that constructivist strategies and technology integration can improve learning in the study of motion and energy.

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INTRODUCTION

Rationale for study

I teach Physical Science, a required course for all high school freshmen. In the past, I have noticed that many freshmen in my Physical Science classes tend to rely on memorizing terms and formulas for tests, and have great difficulty applying their knowledge to solve new problems. Unstimulating teaching methods do not guide and motivate students to make the connection between the science concepts and the world around them (Slavkin, 2002). Some students fall into a pattern of studying just to pass the tests. This "cramming" of new information gives the student little opportunity to build on his previous knowledge, and the new information is quickly forgotten (Sewall, 2002). Many traditional textbook-driven activities seem to lack the depth of concept development necessary for acquiring lasting knowledge. Slavkin attributes this problem to the lack of student empowerment. For example, a velocity lab may have involved taking distance and time data, with which the students could calculate the average velocity of a toy car and graph the distance vs. time data. Students may conduct the velocity experiment and provide accurate results, but did they internalize the information? When students encounter an activity that is interesting to them, they will take the steps to own their learning (Slavkin, 2002). If the velocity lab were turned into a race in which student groups charted distance vs. time slopes on a class graph as a way to compare speeds, the activity might catch the students' interest and motivation that sets them up for enduring understandings. By making the lab more student-driven, the students become the ones who set high standards to reach the goals. As a means to help my students develop an enduring understanding of science, I would like to develop an instructional unit that is more student centered and inquiry in nature while making strong considerations for staying within time constraints, maintaining state curriculum standards and reasonable student behavior.

My primary objective in this study was to improve science instruction by empowering students to construct new scientific knowledge to build upon their previous experiences (Simpson, 2001). The unit that I researched and developed to test this objective is on motion and energy. The activities for this unit were developed during the summer of 2003 in the Department of Science and Math Education under the direction of Dr. Merle Heidemann at Michigan State University. With a more unified, challenging and creative motion unit in mind, I spent the summer session testing and modifying motion and energy activities to fit a constructivist learning approach. Constructivism is a philosophy that students construct understanding for themselves (Lowery, 1997). In the definition of constructivist teaching, there are five components that help describe an effective learning environment: scientific uncertainty, student negotiation, shared control, critical voice, and personal relevance (Aldridge, Fraser, Taylor and Chen, 2000). An excerpt from Haney, Lumpke, and Czemiak (2003) further defines these five components:

> "Teachers who practice constructivism in the classroom present scientific knowledge as arising from human experience and values, evolving and insecure, and culturally and socially determined. They would let students plan and justify their ideas, examine the ideas of other students, and reflect upon the viability of their own ideas, as well as invite students to share control of designing and managing activities, assessments, and classroom norms. Students would feel free to question the teacher's pedagogical plans or methods and express concern about things that may hinder their learning. Finally the science they taught

> would make use of students' everyday experience, and classroom activities would be meaningfully related to students' lives."

The constructivist approach is a good methodology for teaching a technology-rich unit on motion. The LEGO Mindstorm robotics kits and Vernier /Texas Instruments microcomputer based learning (MBL) technology required intensive testing and debugging. I had to keep the technology simple so that the main objective of scientific concept attainment was not lost. Oftentimes, I had to place myself in the student's seat to visualize the effectiveness of each activity.

This motion and energy unit is a crucial opening unit in the course where I want to introduce semester long themes such as process skills, solving basic algebraic equations, teamwork and graphing. Students studying physical science need an engaging, high interest unit that excites them about the study of motion and energy. In this study, I would like to see if students can build on their previous knowledge by emphasizing a constructivist learning approach. The constructivist approach seemed ideal for a motion unit, as many motion concepts are taught with a "do it and see for yourself" approach. In addition, I would like to see if applying the technology of programmable LEGO Mindstorms vehicles and MBL activities provide an efficient and captivating way of learning motion. This unit on motion is taught at the beginning of my semester long course on physical science.

Demographics

I teach a freshman level physical science course at Harper Creek High School. Harper Creek Schools is a suburban school district located in southeast Battle Creek, in

Calhoun County, Michigan. The district covers an area of 82 square miles of residential and agricultural properties. The district serves 2700 students from Emmett, Leroy and Newton townships (Standard and Poor's, 2003). There are three K-6 buildings, one grades 7-8 junior high school, and a grades 9-12 high school. The high school currently has 811 students. 8.9% of the study body are economically disadvantaged. There is a 17.7 to 1 student to teacher ratio. The district MEAP passing rate is 53.0 %, slightly above the state average of 52.8%. Ninety-six percent of the students are Caucasian. There are 237 freshman, with 11 of the freshmen opting to go to Battle Creek Area Math and Science Center for their math and science courses. This study was conducted on two sections of Physical Science students, for a total of 44 subjects. The first section (N=25) was taught in the fall semester of 2003, while the second section (N=19) was taught in the spring semester of 2004. This course is a graduation requirement. The 90-minute class meets daily throughout the semester for a total of 90 days. This course is taught on the four block schedule. On the four block schedule, students have 4 classes per semester. This allows students to take a total of eight courses per year. This semester long course is equivalent to a full year of Physical Science on the traditional schedule. There is great academic diversity in each section, with 17 of the 44 subjects having a cumulative grade point average below 2.4 on a 4.0 scale (the district considers anything less than a 2.4 as a failing cumulative grade).

Scientific Background

Concepts. Mechanics is a branch of physical science dealing with force and energy and how they influence the behavior of objects. Much of the mechanics we know today is based on the knowledge imparted by Sir Isaac Newton. Newton published a complete explanation of the principles of mechanics in a text called *Philosophiae Naturalis Principia Mathematica*, also known as *Principia*, in 1687. One-dimensional motion is an easy place to start the study of mechanics. Take an object that moves a certain distance. An object that changes its position is said to have undergone displacement. This distance is a scalar value, having magnitude, but no direction. An object that has traveled a certain distance over time has a certain speed. There is an instantaneous speed for the speed of the object at a particular place in time. There is also a way to calculate the average speed if you know the initial and final speed of an object. Velocity is speed with direction, where v is velocity, x_f is the final position, x_i is the initial position, and t is the time:

$$v = (x_f - x_i)/t$$

Acceleration is the change in velocity over time, where a is the acceleration, v_f is the final velocity, v_i is the initial velocity, and t is time:

$$a = (v_f - v_i)/t$$

Acceleration results in a decrease or increase in velocity. Vector analysis is an important tool in the study of motion. A vector quantity is one that has magnitude and direction, unlike scalar quantities. In the study of displacement, one can add the component vectors to arrive at a resultant vector. Newton developed three laws summarizing the motion of objects. Newton's first law states that objects at rest tend to remain at rest unless acted upon by an outside force, and that objects in motion stay in constant motion unless acted upon by an outside force. Newton's second law states that the acceleration of an object is directly proportional to the force exerted by the object and inversely proportional to the object's mass, or

$$a = F/m$$

where a is acceleration, F is force, and m is mass. According to Newton's third law, for every action there is an equal and opposite reaction.

Energy is the property of an object or a system which enables it to do work. Energy, unlike Newton's concepts of motion, was not clearly understood until the 1850s. Energy comes in various forms: chemical, mechanical, nuclear, heat, and solar. Mechanical energy includes potential (stored) energy or kinetic energy (energy of motion). Energy is neither created nor destroyed. Energy is merely transferred from form to form, object to object. Work is done when you apply a force on an object and move it a certain distance in the direction of the applied force, or

$$W = F \times d$$

where W is work, F is force, and d is distance. You do work when you climb the stairs because you are lifting your own mass against its weight in the direction you are headed. Power is the rate at which the work is done:

$$P = W/t$$

Where P is power, W is work, and t is time. More power is required if you climb the stairs quickly. The efficiency of a machine is a measure of how much input energy is converted to do useful work:

$$\text{Efficiency} = [AMA/ IMA] \times 100$$

AMA is actual mechanical advantage and IMA is ideal mechanical advantage. The actual mechanical advantage is the number of times a machine multiplies the effort force. The ideal mechanical advantage is the mechanical advantage in the absence of friction. No machine is 100% efficient because a percentage of energy is converted to heat.

A constructivist approach. The educational basis for my activities stems from research on constructivist teaching as a set of strategies used to improve learning in the science classroom (Colburn, 2000; Sewall, 2002; Simpson, 2001; and Yager, 1991). In the constructivist learning environment, students bring in "preexisting understandings upon which new knowledge is constructed" (Sewell, 2002). Constructivism can be traced back to Neapolitan philosopher Giambattista Vico, who wrote, "The human mind can know only what the human mind has made"(Vico, 1858). Mathematician and psychologist Ernst von Glasersfeld has worked with the theories of Vico and Jean Piaget to conclude that "knowledge is not passively received but built up by the cognizing subject" and "the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (von Glasersfeld, 1995). Von Glasersfeld would advocate that rote learning and repeated practice do not necessarily produce real learning. According to Robert Yager (1991), "We can only know what we have constructed ourselves, but such learning always takes place in a social context." In this statement he is showing that a student must take an active part in the process of science before he can own that knowledge. It is important to note that learning is not a solitary activity. Students who discuss the activities with peers will develop more meaning from them. Yager further agrees with Glasersfeld's point of view, emphasizing that cognitive learning does not occur through rote memorization or repeated practice. A review (National Science Education Standards, National Research Council, 1996; Project 2061: Science for all Americans (Rutherford &Ahlgren, 1993); and Biological Science Curriculum Study,1994) of the past decade's research shows that the constructivist approach is so effective that it has become a major component of science reform. Incidentally, our Michigan Standards and Benchmarks are based on the National Science Education Standards. Clearly, many science educators can attest that the constructivist approach to teaching has greatly improved classroom discussions, student performance, and changed misconceptions. The constructivist movement has not lost its momentum in current science education research (Coburn, 2000; Haney, Lumpe, and Czemiak, 2003; Sewell, 2002; Simpson, 2001; Slavkin, 2002). A study was done by Haney, Lumpe, and Czemiak (2003) to see how people in the school setting perceive constructivist beliefs. The research was based on the premise that success in constructivist reform will only exist if the people involved have a strong conviction in the philosophy. Varella and Burry-Stock's (1997) Beliefs about Learning Environments (BALE) Instrument was used to measure the degree of constructivist belief amongst the teachers, administrators, parents, community members, and high school students. Survey results showed that the administrators and teachers possessed the greatest constructivist beliefs, indicating the staying power of constructivist reform in the classroom. The parents and students scored lower than the teachers and administrators on the constructivist perception study, an indication that the constructivist philosophy has not been communicated to parents and students very well. Another source (Simpson, 2001) provides a student perspective that is more supportive of constructivist teaching. A survey completed by 29 fourteen-year-olds indicates that most of the Astronomy and Cosmology unit taught in a constructivist setting exceeded their expectations. Students were given the Constructivist Learning Environment Survey (CLES). The survey is made up of five components that help describe an effective learning environment as previously described by Aldrich, et al, (2003): Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation. Student expectations were met or exceeded in all five scales. This may indicate that the students were generally satisfied with the teaching and learning environment of their classroom. However, their responses also indicate that the teacher still needed to work on becoming more of a constructivist, as he had difficulties giving up "hard control". Students wanted to have more input in what was learned and how it was assessed.

What does a constructivist classroom look like? As previously mentioned, the constructivist approach has become a set of teaching strategies. Not surprisingly, no two authors maintain the same set of strategies. The following is a helpful guide provided by Alan Coburn (2000) for developing a constructivist classroom:

1. provide lab activities before discussing the results students are expected to find
2. discuss labs before lecturing on topics to be taught
3. remove lab data tables so that students generate or organize information
4. change tests to require more concept application by students
5. use a questioning strategy that encourages students to reveal what they're thinking
6. have students develop the procedure to answer a lab question
7. put students into situations where groups debate, discuss, research and share

A more thorough set of constructivist teaching strategies were found in Yager's article (Yager, 1991). Authors Colburn (2000) and Yager (1991) both indicated strategies that encourage students to process knowledge and information on a deeper level, and that improvement in students' understanding of science occurs as a result of helping students align their previous knowledge with that of the scientific community.

There is a lot of classroom research to support the constructivist method of learning. A recent study compares two different educational approaches for teaching physical science (Tretter and Jones, 2003). A physical science teacher compiled data on two different test groups over a four-year period. One test group (N= 94) learned in an inquiry-based style, and the other group (N= 161) learned via a more textbook driven approach. The inquiry group conducted lab work that was of an experimental nature, where students chose which materials to use and developed their own procedures. The textbook group performed the steps in the recipe driven activities and provided answers to questions without necessarily demonstrating understanding of the concepts. The findings show that the inquiry group had a dramatic improvement in class participation, higher grades, and higher achievement across the board. Tretter and Jones (2003) cite student improvements in the inquiry group to be a result of an increase in positive attitudes about learning. Some university professors are coming to the realization that the days of lecturing as an efficient method of transferring information to students are numbered. Thomas Lord (1998), a professor of biology at Indiana University of Pennsylvania, states, "I think one of the biggest fallacies in education today is the belief that content recitation and regurgitation confirms concept comprehension and understanding". There is something wrong with the teaching method when students can get an A in the class but cannot explain a concept or apply it in the everyday world. As more and more college professors are faced with this disturbing reality, they are changing their teaching style to more of a constructivist approach. While many agree that the science content should not be lost, many professors ("New Modes," 1994) maintain that teaching the content using a constructivist approach is a necessary method for teaching students how to think and problem solve. Science teachers want their students to learn the science the way that scientists do science. Regarding the content versus process debate, science teachers still believe that teaching students to be good problem solvers makes up for the small loss in content (Sewell, 2002).

A technology emphasis. Technology and constructivist education can work together to enhance science learning. Students naturally apply constructivist strategies to build new understandings when working with technology. Incorporating technology into the classroom engages more students by utilizing a wider range of intelligences. Multiple Intelligence theory, first proposed by Howard Gardner (1983), has educators personalizing education in the classroom. Goodnough (2001), lists Gardner's eight distinct intelligences as:

1. Verbal-Linguistic: Sensitivity to the meaning and order of words.
2. Logical–Mathematical: The ability to handle chains of reasoning and to recognize patterns and order.
3. Musical-Rhythmic: Sensitivity to pitch, melody, rhythm, and tone.
4. Bodily-Kinesthetic: The ability to use the body skillfully and handle objects adroitly.
5. Visual-Spatial: The ability to perceive the world accurately and to recreate or transform aspects of that world.
6. Interpersonal: The ability to understand people and relationships.
7. Intrapersonal: Access to one's emotional life as a means to understand oneself and others.
8. Naturalist: A sensitily to aspects of the natural world and the ability to recognize patterns in nature.

Traditional schools typically teach to students who possess high verbal-linguistic and logic-mathematical intelligences (Goodnough, 2001). According to Goodnough, teachers can reach more students by personalizing education. "MI theory has the potential to enhance conceptual understanding in science, foster positive attitudes toward science, increase enjoyment of and participation in science, and create more authentic learning experiences in science. A personalized curriculum necessitates a constructivist pedagogy that takes into account students' prior knowledge and how they generate connections between existing knowledge and new forms of learning", writes Goodnough. Goodnough further presents strong evidence in her case study to support her claims that MI theory improves student learning. In her account, "Dave", a high school science teacher, found that teaching using MI theory as a framework for an astronomy unit has increased his students' success.

Other sources (Colannino, et al, 2004; Meers and Wiseman, 2002) cite evidence of MI theory as a vehicle for increasing success in science education by addressing the learning styles of both traditional and nontraditional learners. The study done by Colannino, et al. shows that grouping students in lab groups with a mix of intelligences (specifically logical/mathematical, verbal/linguistic, interpersonal, and naturalistic) resulted in higher lab report grades as well as a higher number of lab reports turned in on time. Grouping non-traditional students with traditional students allows hands on learners to excel alongside the book smart learners. In one study (Meers and Wiseman, 2002), the Teele Inventory of Multiple Intelligences (Teele, 1994) was suggested as a tool for placement of students into the appropriate physics class. The "theoretical" physics students tested high for the logical/mathematical intelligence, while the "applied" physics students scored high in the bodily/kinesthetic and intrapersonal intelligences. In an intellectually diverse classroom, a mix of "theoretical" and "applied" physics should be taught as a means to engage students with bodily/ kinesthetic intelligences as well as the logical/mathematical intelligences . Sources (Collanino, et al; Goodnough; Meers and Wiseman) suggest that learning motion through use of technology may provide more students an opportunity to attain success.

Technology can be a great tool for using the constructivist approach in the science classroom. A group of Bloomsburg University math professors applied for and received a grant to develop a course for middle school teachers that would help students understand the importance of problem solving as a process. The grant money was used to train teachers in a summer 1999 course entitled, "Implementing LEGO Mindstorms in the Middle School Classroom". These teachers subsequently worked alongside students in a summer camp setting (Mausch, 2001). The LEGO Mindstorms system is a programmable robotics kit that has a built in computer program. This kit allows students to design, build, program, and manipulate their own robots. At the end of the program, teachers provided feedback to the Bloomsburg University math professors regarding the use of the robotics system as a teaching tool. The teachers largely commented on the robotics systems as a problem solving activity that strengthened students' process skills. From the perspective of the students, they had to build a "toy" that would perform the desired function or functions. In order to achieve their personally created goals, they had to go through various problem-solving steps to arrive at the desired results. These students were intrinsically motivated by the novelty of the project. Students could evaluate their own work throughout, as the robot would only perform correctly if it was constructed and/or programmed correctly. The process required less teacher intervention as the students became more proficient in the programming and understanding of the mechanics of their robot. Students also discovered the importance of communication skills as they worked within their problem solving groups.

In addition to the LEGO Mindstorm kits, Texas Instruments' TI-83 programmable calculators and Vernier probes as equipment in micro-computer based labs (MBL) have been found to be excellent teaching tools for problem solving in the high school science classroom (Svec, 1999). The question is, do these tools actually enhance student learning? Research shows that using micro-computer based labs in the study of motion can improve student understanding, especially in graphing interpretation. A study done with undergraduate introductory physics students (Svec, 1999) demonstrated improvements in conceptual understanding as well as an increase in graphical skills. The control group had traditional labs while the experimental group conducted microcomputer-based labs. After completion of the course, the experimental group had learned more about graphing interpretation skills, motion graphs, and had a deeper conceptual understanding of motion.

There is strong evidence to support that combining hands on learning with MBL technology increases student understanding of motion. Jonte Bernhard of Linköping University in Sweden has found that students who perform mechanics labs with technology that allows them to see real-time data show greater gains in conceptual understanding of motion than those students who are taught without the hands on/technology combination (Bernhard, 2000). He warns us that the technology is only as good as the teaching approach, however. The traditional lab is a hands-on "cookbook" lab that may use the MBL equipment simply to verify a formula. This traditional lab may not address the student's misconceptions. The educational approach to teaching the MBL/active engagement students involved the use of MBL technology as a way to test the students' predictions. The real time data provides the students with immediate feedback to their predictions. The result of Bernhard's study shows that students taught under the MBL/active engagement approach performed significantly better than students taught using the traditional formula verification approach.

Finally, here is one more example of the constructivist approach and technology integration working together to maximize students' conceptual understanding (Oakes, 1997). The context is a lab on gas laws. A traditional lab would provide students with Boyle's law and ask them to verify the equation by conducting the experiment and graphing the results. Students can conduct the experiment, generate the correct graph, and find that the graph follows an equation that they already know. A constructivist approach would allow the student to build the formula. From conducting the experiment, students would go through the process of predicting how pressure and volume under constant temperature are related. Students can get excited about discovering the relationship themselves before ever being taught the equation or concept of Boyle's Law! The students formulate a relationship the way scientists do, which is characteristic of the constructivist approach. Use of graphing calculators and MBL sensors helps students to maximize their graphing skills and graphing interpretation.

IMPLEMENTATION

In delivering the motion unit to my Physical Science classes, I had to narrow down the material to the essentials. At the same time, neither the content nor the process could afford to be sacrificed. A unit pretest was given to gather baseline data. The unit is structured around 15 activities that were taught with the constructivist approach and technology integration in mind. Students completed an activity survey at the completion of each activity. Additional support materials were used as learning supplements. At the end of the unit, a post test was given to measure growth and areas of concern.

Before instruction of the unit, a unit pre test was given to gather baseline data and guide student instruction (Appendix C-I). The unit pretest is an objective test that measures twenty four separate concepts: 1) speed, 2) graphing speed, 3) calculating velocity, 4) velocity/time graph, 5) converting a distance/time graph into a velocity/time graph, 6) calculating acceleration, 7) free fall, 8) free fall and air resistance, 9) Newton's first law, 10) Newton's second law, 11) graph acceleration versus force, 12) Newton's third law, 13) potential versus kinetic energy, 14) pendulum (length and energy), 15) potential and kinetic energy of a rollercoaster, 16) definition of work, 17) work and power, 18) define power using the terms work and time, 19) actual mechanical advantage versus ideal mechanical advantage, 20) efficiency, 21) gear directions, 22) mechanical advantage versus speed advantage, 23) simple machines, and 24) complex machines.

The motion unit is laid out in a sequence that allows for students to build their understanding of motion, from simple to complex concepts (see Table 1). Table I shows that the unit is divided into four sections: 1) Linear motion (distance, velocity and

Week	Topics	Activities (* new to unit)	Additional materials (* new to unit)	Glencoe Textbook Correlation (this text was used with this unit)
1(5 days) 2 (5 days)	Linear Motion: Distance, velocity, acceleration Free fall	1. Determining Distance and Velocity* 2. Interpreting Position vs Time Graphs* 3. Velocity: Constant or Changing?* 4. Acceleration* 5. Free Fall* 6. Vector Addition* (1st semester)	-Unit pretest* -Velocity and acceleration practice -Distance, velocity and acceleration quiz -Assessment: Train Mystery*	Ch 3 -Section review problems p69#2,3 -Review problems p89#1-3,10;p90#1,3-5,10,12,17-20 Ch 4 -Section review problems p99 and 105
3(5 days)	Newton's Laws	7. Newton's Laws Demos* 8. Constructing Newton's 2nd Law* 9. Newton's 3rd Law: Action and Reaction*	-Chapter 4 Practice Problems - Chapter 4 Newton's Law s Quiz - Chapter 4 Test: Newton's Laws*	Ch 4 -section reviews p109 and 116
4 (3 days)	Energy	10. Energy of a Swing 11. Rollercoaster* 12. Work and Power*	-NOVA Rollercoaster video worksheet*	Ch 5
4(2 days) 5(4 days)	Machines	13. Which Machine is More Efficient? 14. Gear Ratios* 15. Turtle Race*	-A Lesson on Mechanical Advantage* -Test on Energy and Machines* -Motion Unit test (post test)*	Ch 7

Table I. Motion and Energy Unit Schedule acceleration), 2) Newton's laws, 3)Energy, work and power, and 4) Machines. Activities developed for analysis are located in Appendix A. Most of the activities highlighted in this research unit (Appendix A) are discovery activities designed to allow the students to confront their misconceptions and correct them through experimentation. . In an attempt to reach a broad student base, most of these activities require the inclusion of varying multiple intelligences. For example, problem solving may be enough for the logical/mathematical group when it comes to interpreting velocity. To include more students in the active learning process, I have attempted to incorporate more intelligences such as the bodily/kinesthesis and visual/spatial intelligences. In the first three linear motion activities (appendix A-I through A-III), LEGO programmable robot vehicles are used with the different intelligences in mind. The bodily/kinesthetic student understands the concept of velocity by physically observing an object cover a certain distance in a time period. For example, students in *Lab: Determining Distance and Velocity* (Appendix A-I) program and observe the distance and time data for the linear motion of a robot as a way to find velocity. Interactions between group members help the interpersonal or verbal/linguistic students to maximize their learning. Throughout the LEGO Mindstorm-based labs (Appendix A-I, II, III, and VII, and XV), students worked in groups of four. Each student had a task: one student was a builder of the LEGO robot, another student programmed the robot, one student organized the LEGO pieces, and one student kept the group's journal. For Lab*: Interpreting Position vs. Time Graphs* (Appendix A-II), one student would construct the car. Another would program the RCX box after the car is built. A third person is there to record data, while a fourth is keeping track of and organizing all the LEGO pieces. The students must rely on each other to finish the lab. The builder has to communicate with the programmer so that the programmer knows what the capabilities of the car are. The data person has to communicate with lab partners and record information clearly on paper. The organizer must use patience and determination to maintain the efficiency of the building process while working with the builder.

Support materials are located in Appendix B. I gave each student a unit packet at the beginning of the unit. This unit packet is a place for students to keep a journal, take notes, draw pictures of concepts, and give personal examples of concepts during our daily discussions. At the end of the first day in the study of motion and speed, I asked them to write a short story using the terms distance, velocity and acceleration . I read the stories to check their prior knowledge of the terms. My initial lectures are really dialogues with students to bring out their misconceptions and predictions about the topic. I did demonstrations based on the constructivist perspective that a demonstration should either be a discrepant event or a prediction (Colburn, 2000). I may start with a demonstration that is a discrepant event, an event in which the outcome is not as the students expect it. For instance, if I am demonstrating the conservation of energy, I stand at my chalk board and release a pendulum from in front of my face. When the pendulum returns near my face, some students are surprised to see that the pendulum does not hit my face. In demonstrating Newton's first law I like to balance a wire headgear (two clay balls attached to the ends of the wire) on top of my head and ask students to predict what will happen if I turn around (see Figure 1) .

Figure 1. Newton's First Law Demo

They often predict that the clay headgear will spin with me. Asking them to predict what will happen forces them to access their previous knowledge, a general means of constructing new knowledge. I then ask them why the headgear does not spin with me. Asking them to explain what they see after the demonstration is a way to test student understanding.

Students filled out the Student Survey of Motion and Energy Activities form (Appendix C-III) after the completion of each activity, as a way of reflecting on the concepts taught and providing feedback about the effectiveness of each activity. Students were briefed on the topic of constructivism as a teaching and learning approach so that they could respond to the survey question regarding the effectiveness of constructivism in their understanding each activity.

Each activity was further reinforced with textbook problems, worksheets, and other materials. For example, students were assessed on position and time graph interpretation by doing the homework at the end of Lab: Interpreting Position vs Time Graphs (Appendix A-II). Students were exposed to graphing and graph interpretation again in *Lab: Velocity: Constant or Changing?*(Appendix A-III). This time, the homework exercise at the end of the activity asked the student to draw correct velocity-time graphs from given position-time graphs. By looking over the student performance on the homework exercises, a teacher can quickly determine if students understood the activity or not. Each activity within a section was deliberately designed to build off the previous activity. Activities that require more math background were supplemented with math problem worksheets. For example, the *Velocity and Acceleration Practice* worksheet (Appendix B-I) provided students with the opportunity to learn the Find/Give/Solve process of problem solving. In this process of problem solving, students first *find* what they are solving for, then they list what is *given* as known values, finally they *solve* the problem. After *Lab: Free Fall* (Appendix A-VI) was completed, students solved a story problem as they predicted and calculated the timing of a falling boulder on an oncoming train in *Train Mystery* (Appendix B-III) . Students, especially the visual-spatial learners, enjoyed making the moving picture book of the falling boulder and the approaching train.

Finally, a section assessment was given in the written or performance format. A unit assessment was given as a post test to measure student performance after instruction of the unit (Appendix C-II). In addition, the Student Survey of Motion and Energy Unit (Appendix C-IV) was given to obtain student feedback about the unit.

Implementation of the motion unit was very similar for both test groups. However, several modifications were made with the second semester group. The linear motion activity *Lab: Vector Addition* (Appendix A-V) was omitted from the unit for the second group. The Potential and Kinetic Activity was modified from a pendulum lab (Appendix A-X) to a rollercoaster construction activity (Appendix A- XI) for the second group. In addition, only the second group did *Lab: Turtle Race* (Appendix A-XV).

ACTIVITY DESCRIPTION AND ANALYSIS

In this section of the paper I will begin with an introduction to how the LEGO Mindstorms worked in the classroom. After the Mindstorms background, I will discuss each activity within the four unit sections: 1) Linear motion, 2) Newton's Laws, 3) Work, Power, and Energy, and 4) Machines. I will give a description of each activity, followed by an analysis. The analysis includes student quotes and comments gathered from the Student Activities Survey (Appendix C-III), and an approximate percent mastery level. Mastery of each activity is based on a grade of 80% or above. Non-mastery of an activity does not necessarily indicate failure. Most reasons for not achieving mastery include failure to complete activity, lack of motivation, poor work habits, and inattentiveness. Learning disabled students fared just as well as the mainstreamed students in the mastery of these activities. However, learning disabled students did require more time to complete some activities.

LEGO Mindstorms hardware and software

LEGO Mindstorms kits include hardware and software. A useful website for information on Lego Mindstorms sets for schools can found by logging on to www.lego.com/dacta/robolab/home.asp.

I will briefly describe how the LEGO Mindstorms works as it is important to the understanding of the LEGO based activities that follow. The essential parts to using the Lego Mindstorms kit include the programmable microcomputer called the RCX and an infrared transceiver called the IR tower. The IR tower is the device for downloading software and student made programs to the RCX via a USB connection on a PC. The kit also has motors, light and motion sensors, and about 720 other building pieces. Students build models and robots using the RCX as the "brain". They then use the Mindstorms software to write a program and upload it to the RCX via the IR tower. The RCX can have as many as 3 motors, each of which can be programmed to go forwards or backwards, with a choice of 8 different speeds. The RCX has 3 input ports to connect environmental sensors (motion, touch and light, for examples).

There are two different software programs that I tested for use with LEGO Mindstorms: the Robotics Invention System 2.0 and the RoboLab 2.5. I found the Robotics Invention System 2.0 to be more user friendly and chose to use it for all LEGO Mindstorms activities in this unit. The RCX code is a visual, icon-based programming software. Blocks of code that represent commands such as left or right turns, sound effects, pauses, sensor settings , and motor speed, to name a few, are available for the program builder. Students can drag and click the blocks, attach them in a logical order, and have a program in a matter of minutes. The program is then ready to be uploaded to the RCX. By hitting the "run" button, the RCX model or robot goes into action. Students can design, program, and build a simple robot within a 90minute class period. Figure 2 is an example of a "Legobot" that was built by one of my student groups.

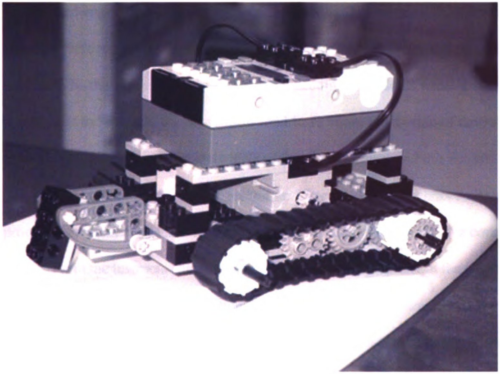


Figure 2. A LEGO Mindstorms vehicle

Section 1: Linear motion

The linear motion section incorporates five activities. *Lab: Determining Distance and Velocity* (Appendix A-I) is an exercise in calculating velocity under the guise of a precision competition. Students are asked to program their robot to stop exactly at the 1-meter mark on a linear track. Their first day was used to introduce them to robot construction. They had to build a car with uniform wheels. On the second day, they were taught how to program their RCX box . They were asked to program their robots to travel in a straight line at a constant speed and stop precisely at the one-meter mark. The activity sparked their interest in robotics and exposed them to the concept of average velocity. Students found that they had ownership of the activity, as they were given the freedom to build, program and troubleshoot their own robot vehicle. Most students commented on the activity as being more interesting than learning from the textbook. Students were motivated by the objective of the lab and they gave it their all to get their vehicle to be the most precise within a given deadline. Students wrote that they thought it was good to "actually see the motion" and learn about the motion of the vehicle in a step-wise manner. Approximately 80% of the students mastered this activity.

Lab: Interpreting Position vs. Time Graphs (Appendix A-II) is a logical progression as students learn how to equate the motion of a robot with a corresponding graph. Part One instructs students on how to generate a graph from the path that the robot traveled. Students are able to check their graph by comparing it with the graph generated by the MBL equipment. In part two, students are given a graph and asked to program the robot to walk a path that matches that graph. Again, to verify their work, students must match the MBL generated graph to the given graph. This activity allowed the students to connect the physical motion with the mathematical calculations and graphing analysis. Students related that they can really see what the connection was when they "put the graph into action". About 75% of the students mastered this activity.

Lab: Velocity: Constant or Changing (Appendix A-III) addresses the change in velocity that leads to acceleration. Rather than introduce acceleration up front, students discovered it for themselves. After having programmed the robot to increase in speed over a certain period, they saw that the robot changes its speed. Graphing velocity vs. time gives students another way to visualize a change in speed. Students were sent home with exercises involving the translation from a position vs. time graph to a velocity vs. time graph for reinforcement (Appendix A-III). Some students had trouble converting position vs. time graphs into velocity vs. time graphs. They did not see how to use data from a position vs. time graph to calculate velocity values. Regarding the activity, a significant comment from a student was, " … because its cool how everything works by programs you designed". About 70% of the students mastered this activity.

By the time students work on *Lab: Acceleration (Appendix A-IV)* they know that a change in the velocity of an object indicates that the object either sped up, slowed down, or changed directions. This became a good time for them to develop the calculation for the acceleration of an object. Simply giving them a formula and asking them to solve for acceleration doesn't help students develop a working understanding of the concept, so in *Part I* of this activity we used photogates to find initial velocity, final velocity and the change in time. Students used this information to calculate acceleration of a cart on a track. For comparison, students used the motion detector to help them arrive at acceleration of the cart in *Part II.* The consistent use of technology in this lab contributed to the students' deeper understanding of acceleration. Students cited ease of use and understanding, time efficiency, interest, and collecting accurate data as reasons for liking technology in this lab. Student comments such as "This equipment is really cool..", "I actually got good results", and "This lab was easy and I get it!" confirm their excitement about the technology. Approximately 70% of the students mastered this activity.

In *Lab: Free Fall* (Appendix A-V) students examined air resistance and terminal velocity. Students used a motion detector to measure the vertical acceleration of dropped objects. Students were asked to explain why different objects may experience a difference in air resistance. Based on the student survey, the lab gave them a working understanding of free fall, air resistance, and terminal velocity. Students in the first group commented that a lot of troubleshooting was necessary to get the MBL equipment to generate good results. "I spent most of my time getting the CBL to work" was a common complaint from the first semester group. Seventy percent of the students mastered this activity.

Lab: Vector Addition (Appendix A-VI) was an activity done only by the first semester students. Students learned that the sum of the vectors is the shortest distance between the beginning and end of a path. LEGO vehicles were built and programmed to move from start to finish in four moves, using only forward blocks and right angle turns. Students drew the vectors on graph paper and graphically found the resultant vector. If properly graphed, students could use the resultant magnitude and direction to program the robot to go from start to finish in one move. Students understood what they had to do, but they commented on their survey that getting the LEGO vehicle to match the graph was a challenge. "The bot would not do what I programmed it to do" was a typical comment. Of the first semester group, 65% mastered the activity. Due to the difficulties with programming the Mindstorms vehicles to perform the required tasks, this activity was removed from the unit after the first semester. Students found it extremely difficult to make the robot complete perfect right angle turns. As a result, their results were not close enough to the predictions, and students were disappointed in that. No replacement activity was created for the second group.

Section 2: Newton's Laws

Each of Newton's laws was introduced with a demonstration. *Newton's Laws Demos* (Appendix A-VII) is a series of demonstrations that prompted the student to challenge personal beliefs and make predictions of what will happen. In crash test #1, students saw the board stop the car at the end of the ramp. In crash test #2, students had to make a decision as to whether the unsecured Barbie would be stopped by the board or continue traveling off the ramp. Students either confirmed or challenged their beliefs as they saw Barbie continue off the ramp while the car was stopped by the board. Finally, students could see Barbie as a part of the system as the seatbelt kept her from falling forward when the cart hit head on into a "wall". Many students believed that objects with more mass fall faster. To challenge this belief, marbles of different mass were rolled down a ramp simultaneously. In another demonstration, students were asked to predict how mass affects the horizontal acceleration of an object, force being constant. Lastly, to encourage students to construct Newton's Third law, I challenged two students to test their strength by tugging at a horizontal rope with two spring scales tied to both ends. They soon discovered that neither one wins as the scales are equal- the tension of the rope is the same throughout! This was not a graded activity.

Lab: Constructing Newton's Second Law (Appendix A-VIII) is an MBL activity that uses a force sensor and an accelerometer hooked up to a cart on a track to examine the relationships between force, mass and acceleration. Students had an opportunity to formulate Newton's Second Law from their data. Student comments included, "You can understand it because you can actually see it" and "the graphs help you see the acceleration of the cart". Student comments referring to technology use included "hands-on makes it brains on for me" and "I enjoyed learning by using equipment (accelerometers and force sensors) that I never knew existed". One student stated that the MBL technology made the calculations and the F=ma (force equals mass times acceleration) relationships easier for him to understand. Approximately 70% of the students mastered this activity.

Lab: Newton's Third Law (Appendix A-IX), although it does not use MBL or LEGO Mindstorm equipment, uses the same constructivist learning strategies that are evident throughout this unit. In this activity, students constructed and analyzed a series of seven action/reaction set ups using pulleys, ropes and spring scales. At the conclusion of the activity, students were asked to explain the statement " for every action there is an equal and opposite reaction". Students liked the many tests that were done to reinforce their understanding of how action forces exert an equal and opposite force. A student comment was, "Seeing the force values on the spring scale made it easy to understand opposing forces". Student mastery on this activity was about 90%.

Section 3: Energy, Work, and Power

Energy is a necessary topic in the study of motion. The efficiency of a machine can not be considered without considering mechanical energy. For a potential to kinetic energy transfer problem, *Lab: Energy of a Swing* (Appendix A-X) was tested by my first semester students. Students determined if a pendulum would continue swinging if a crossarm is placed in its path. Students examined the concept of energy transfer and compared kinetic with potential energy. The scenario set (the pendulum as a swing at the park) created a hands-on model for the students to visualize. Student mastery of this lab by the first semester group was about 70%.

I did not like the lack of direction in this inquiry lab. This activity was so open-ended and disjointed that students did not not pick up on the main idea of energy conversions. I replaced it with *Lab: Rollercoaster!* (Appendix A-XI) for the second group. Students tried their hand at designing and constructing a model rollercoaster that showed the potential to kinetic energy transfer. Students analyzed the motion and energy of a marble as it traveled down the model rollercoaster. Students discovered the energy conversions for themselves as they used trial and error to build the requirements into their marble coaster. Students commented that they enjoyed the challenge of building the rollercoaster. "Our group's rollercoaster was the best!" beamed one student. Some stated that did not enjoy doing calculations from the rollercoaster data by writing, "Building the coaster was fun, but I did not like all the math involved." Approximately 75% of the students received a mastery grade on this activity.

Activity 10: Work and Power examines the power of a "pull back" car as it travels up an incline. Students timed how long it would take for the car to travel one meter to the top of the incline. The incline had a set vertical height. As an extension, students calculated the work and average power of the toy car and compared it to the power of their LEGO car. Students commented that they found the activity interesting and enjoyed working with the pull back cars. One student said, "I want to do more labs like this one". Student mastery was about 75% for this activity.

Section 4: Machines

In *Lab: Which machine is more efficient?* (Appendix A- XIII) students set up, record data, and complete calculations to find the efficiency of three simple machines. The machines include an incline, a block and tackle pulley system, and a lever. Students compared and calculated the efficiencies of each machine using two different formulas for efficiency: (W_{in}/W_{out}) x 100 and (AMA/IMA) x 100. Finally, students were to compare two things: 1) efficiency values for each machine, as calculated by using two different equations, and 2) differences in efficiency between the machines. Students commented that the activity was very visual and helpful in constructing the concepts and understanding them. Students said that the directions for calculations weren't always clear. Student comments included, " I could see all the simple machines and use them to solve the problems" and " "The calculations were confusing." Approximately 70% of the students mastered this activity.

In *Lab: Gear Ratios* (Appendix A- XIV) students built a model of the bicycle gear combination. This laboratory uses LEGO gear chains and gears to demonstrate how mechanical advantage and speed advantage vary with the change in gear ratios. Students can physically turn the "pedal" to tell which gear combination has a high mechanical advantage or high speed advantage. As they turned the gear, students visualized the speed of the rear gear and used reasoning to determine which combination is best for racing on a level track or climbing uphill. Students stated that the LEGO bricks, axles, gears, and gear chains "were an excellent tool". One student wrote, "It was awesome how you could use LEGO parts, especially the gear chains". Approximately 85% of the students mastered this activity.

Activity 14: Turtle Race is the grand finale of the unit (See Figure 3). This activity was only done with the second semester group, as I did not have enough time to do this with the first semester group. The mission was to build a racecar that is last to the

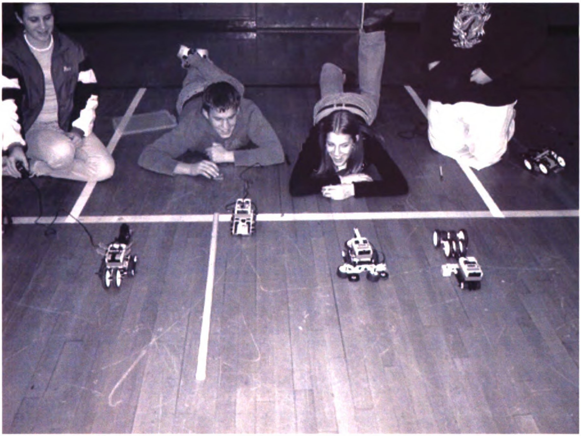


Figure 3. The Turtle Race is on

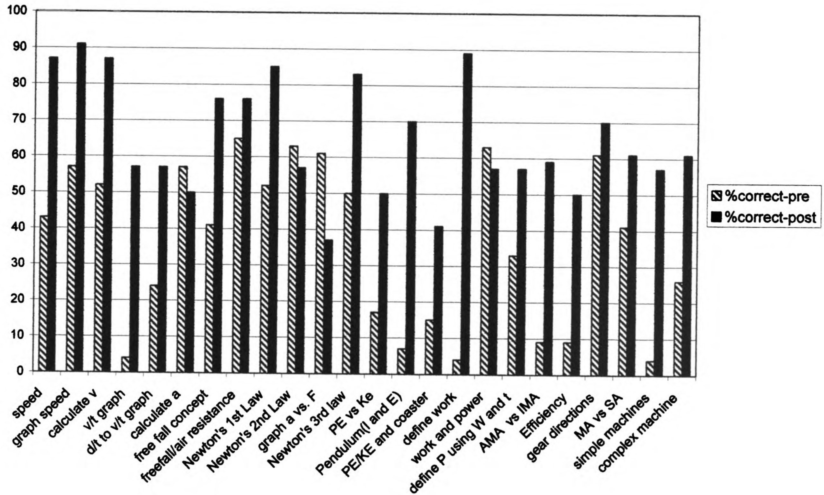
finish line. There were limitations- the car had to be built entirely from LEGOS, including the RCX. The car had to be started by a sensor and had to move forward in a straight line without hesitating. This was an extremely creative challenge and made an excellent end project for the students. Students used all of their skills that they had been using during the unit to build a car that met the race specification. Consideration of RCX programming, car design and construction, friction, Newton's 2^{nd} Law, and gear ratios were made as they put their final project together. Students assessed their own performance as they built the car. When the car did not do what they wanted it to, they had to troubleshoot to figure out what went wrong or how to modify the car to do what they wanted. Sometimes the programming was not correct and they had to coordinate that with the car. A student asked me at the end of the project, "Can we do this for one more day?" Another student wrote, "This lab was hard, but I really got a lot out of it". Students stated that they enjoyed the challenge of this activity. Many mentioned that this activity was a good review of the concepts studied in this unit. About 85% of the students mastered this activity.

RESULTS

Objective data includes *Unit Pre/Post Test Results, by concept* (Appendix C-V) as well as *Unit Pre/Post Test Results, by student* (Appendix C-VI). The conceptual data was compiled to show strengths and weaknesses within the unit. The student data was collected to reveal any patterns in student improvement from pre test to post test. The pre and post test results show considerable growth across the unit.

Table 2 shows that before teaching the unit, only nine concepts were understood by a majority of students (more than 50%). The nine concepts included: 1)graphing speed, 2)calculating velocity, 3)calculating acceleration, 4)freefall/air resistance, 5)Newton's first law, 6)Newton's second law, 7)graph a vs. F, 8)work and power, and 9)gear directions. According to the state of Michigan standards and benchmarks, instruction on motion at the middle school level includes 1) two-dimensional motion using speed and direction, 2) motion of balanced and unbalanced forces, 3) gravity (which includes the discussion of forces, mass, and weight), and 4) simple machines (mechanical advantage and speed advantage). Middle school instruction on energy includes energy transformations and conservation of energy. After teaching the unit, results indicate improvement in twenty of the twenty four topics tested. Major gains occurred in the following concepts: v/t graph, pendulum (length and energy), define work, AMA vs IMA, efficiency, and simple machines. However, student performance went down in calculating acceleration, Newton's second law, graph of a vs. F, and work and power. Student weaknesses appeared in acceleration, Newton's second law, and potential/kinetic energy, as seen in the declining or low post test scores. *UnitPre/Post*

Table 2. Graph of Pre and Post Test Results by Concept; N = 44



Test Results, by student (Appendix C-VI) show that all students improved from pretest to posttest. In addition, the percentage of students passing (60% or above) rose from 7% before instruction to 75% after instruction. For clarity, results and analysis are shown by class (Tables 3 and 4).

Table 3. Pre and Post Test Results by Students, First Semester Group; N = 25

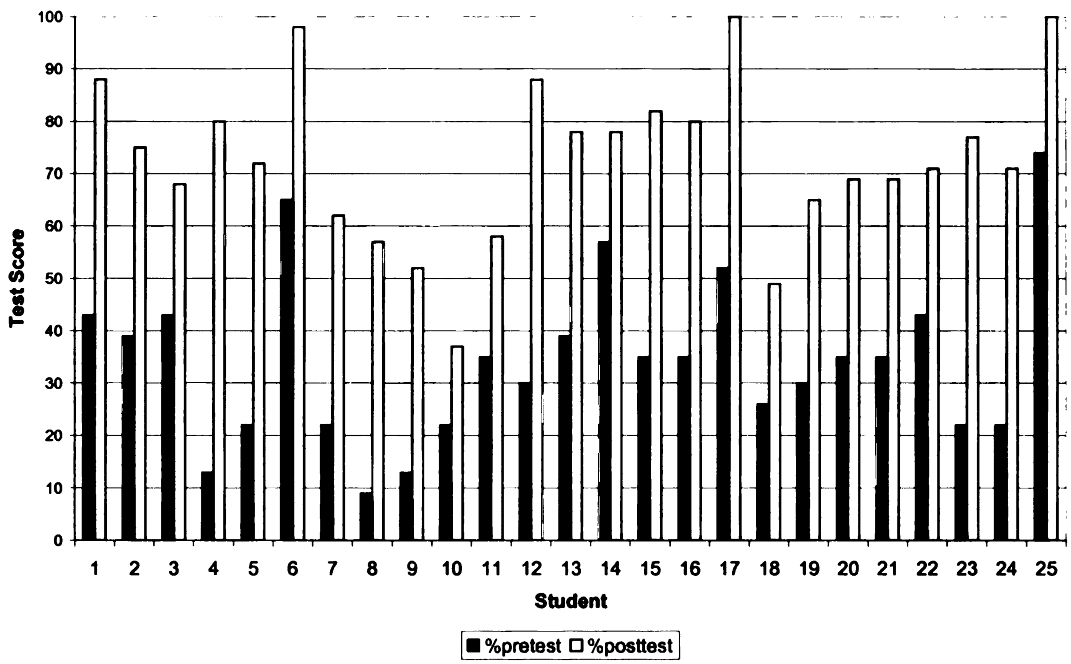
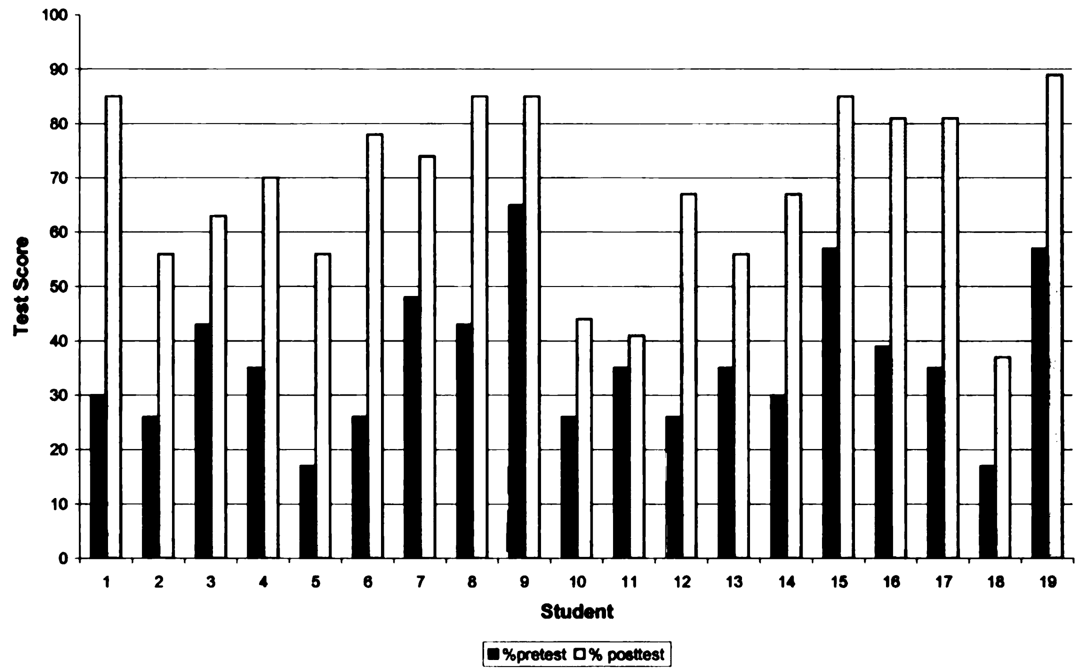


Table 4. Pre and Post Test Results by Student, Second Semester Group; N = 19



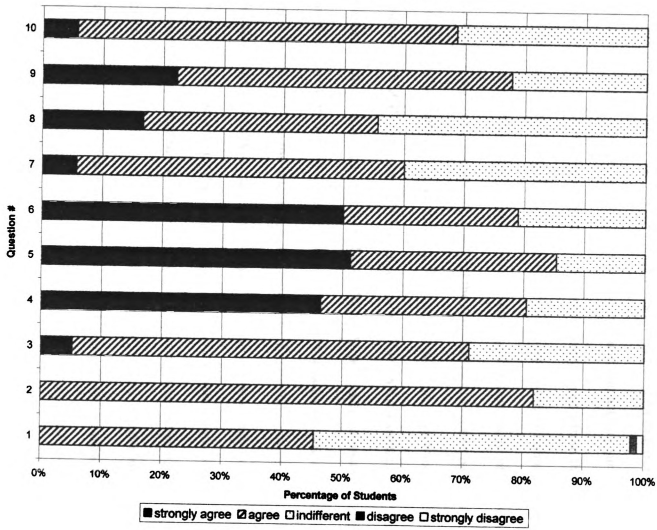
Using the paired Student's *t* test, a statistical analysis of the pre and post test results by student (Appendix C-VII) was done. For the first semester group, $t_{25} = 15.1$ and p= .001. For the second semester group, $t_{19} = 10.9$, and p= .001. Both statistical sets indicate that the pre and post tests are statistically different. Additional calculations, based on *Motion Unit Pre and Post Test Results* (Appendix C- VI), comparing the first semester group to the second semester group on the unit pre and post test were done (Table 5).

	First Semester Group	Second Semester Group
Passing the post test with a score of 60% or above	80%	68%
Group average for pre test	34%	36%
Group average for post test	73 %	68%
Pretest – Post test	+39%	+32%

Table 5. A group comparison of pre and post test calculations

The *Motion Unit Survey* results (Appendix C- VIII) indicate that students value technology as a motivator and aide in learning motion. Table 6 summarizes the results of the Motion Unit Survey. Ease of understanding score lowest in this survey, with only 43.2% agreeing to the statement that the unit activities were easy to understand (Table 6, question 1). Over sixty one percent of the students agreed that the time spent on each topic was appropriate. When asked in question #4 if applying technology in the science classroom was fun, 75% of the students agreed or strongly agreed. 79.5% of the students agreed or strongly agreed that learning was easier with the use of technology, as seen in question 5. Over 60% of the students agreed or strongly agreed that the LEGO Mindstorms activities inspired their interest in the fields of computer programming and engineering (Table 6, question #9). When asked if graphing data helped them understand relationships in motion, 47.7 agreed or strongly agreed. Over half (54.5%) of the students agreed or strongly agreed that use of MBL technology helped reinforce skills taught in math class. Regarding the use of constructivist approach in the classroom(Table 6, questions # 3 and 6), 60% of the students agreed or agreed strongly that the approach was helpful in their learning process. Results for #8 were only taken for the second group. "The final project reinforced my understanding of the unit concepts", were only taken for the second group. Of the second semester students, 54.6 % agreed or strongly agreed to statement # 8.

Table 6. Student Unit Survey Results, N = 44



DISCUSSION/CONCLUSION

Implications of the Data

My interpretation of the effectiveness of this unit is based on data from the unit pre and post test tests, student activity performance, and unit and activity surveys.

A growth in knowledge in twenty of the twenty four concepts from the pre test to the post test may be due in part to the instructional practices used in this unit. Constructivist strategies such as designing and conducting experiments, troubleshooting, analyzing data, and group collaboration helped the students become active participants in the study of motion and energy. In addition, technology components such as LEGO Mindstorms and MBL tools stimulated the students' motivation for learning. Growth in such a large portion of the concepts may also be due to the personalized instruction that occurred as more learning styles were incorporated. The four items that the students did not seem to grasp include the calculation of acceleration, interpreting a force versus acceleration graph, identifying points of high potential and kinetic energy on a rollercoaster, and calculating efficiency. Despite the constructivist nature of the activities, the hands-on nature of the technology, and the reinforcement of support materials, up to 46% of the students got questions related to these ideas wrong. For the calculations of acceleration and efficiency, some students could not translate math problems into conceptual problems, and they simply froze up when asked to solve a problem on their own. Most likely, some students have poorly developed math skills. For the Newton's second law question, given a force versus acceleration graph, students were asked to identify the variable represented by the slope. Only 34% of the students could make the connection that F/a gives you a slope that corresponds to the mass of the object. Students simply did not see this relationship. I will attempt to have students interpret the slopes of other relationships when teaching this concept, as a way of getting this idea across. Low achievement on the kinetic and potential energy question may result from lack of enough examples presented in class. Having the students come up with the examples would be a good constructivist strategy, as it provides relevance to the learner. I would like to have students identify the points of maximum and minimum potential and kinetic energy on more examples, as a way to reinforce this topic. This data tells me that some students need more intensive help with problem solving after school. This would be an appropriate constructivist strategy to help students close some gaps in their prior knowledge base. Again, closing these gaps would allow the students to have a stronger knowledge base from which to build new knowledge.

A comparison between the first and second semester groups by pre and post test results is interesting. Overall, the first semester group performed better on the post test than the second semester group. The first semester group had a larger percentage of students who were engaged and who had positive behaviors. From my observations, the first semester group had a larger percentage of students who valued education more than the second group.

Student performance on the activities (refer to Activity Description and Analysis) was realistic. Student grades for activities in the motion unit were comparable to grades on activities in other units. The approximate activity grades average from a low of 65% to a high of 90%. On average, students did well on the performance skills such as building LEGO vehicles, recording observations, and troubleshooting MBL equipment, as can be seen by higher scores on conceptual activities such as *Distance and Velocity, Newton's 3rd Law, Gear Ratios, and Turtle Race* (See Appendix A-I, IX, XIV, and XV for activities). More students had difficulties transferring hands-on information into more abstract relationships, as evident in the lower scores on the following activities: *Acceleration, Newton's 2nd Law, Work and Power, and Which Machine is More Efficient?* (Appendix A-IV, VIII, XII, and XIII).

The above results seem to reflect the constructivist belief that students learn what they can build onto their preexisting knowledge. Perhaps the more conceptual activities are linked to what they are familiar with in their everyday lives. As a result, students have success with building on their prior knowledge (assuming this knowledge has a sound foundation). As for the more abstract activities, they may have to be tailored so that students have to confront their misconceptions. For example, if a student calculated efficiency values above 100%, he or she needs to give examples of this possibility in other machines and defend it. By searching for other examples and not finding any, the student will perhaps understand that a machine cannot produce more useful energy than it uses. For abstract activities involving math, I will emphasize that the calculations are followed up with written explanations. When students explain their own solutions, they may find the weaknesses in their argument and be able to correct their own misunderstanding. General strategies that I will use to improve the more abstract activities include: using examples and materials that students are familiar with; and providing students with more opportunities to design the experiments. Perhaps these strategies will allow students to find the information more meaningful and will therefore improve retention of information, as Slavkin (2002) suggests.

Results of the student surveys of activities (Appendix C-IX) provide insightful information about the effectiveness of the constructivist approach and technology integration in learning motion and energy concepts. Student survey results show that the student centered activities appealed to the students. In student centered learning, such actions as the following are evident in the learning process: students ask the questions, students find the topic relevant, students find their own resources, students plan their activity (Yager, 1991). Student surveys confirmed that these student centered actions as described by Yager occurred while performing activities in the motion unit. The self-motivation that they experienced could have stemmed from personal interest in technology, student developed challenges, and ownership in the making of a unique product. In many cases, students' expectations of meeting the goals were higher than the ones I had set for them. In some activities (Appendix A-I , A-XI, A-XV), they felt the need to challenge each other. There was a tendency for students to see if they can build the faster car, or the most different car. Most evident in the *Turtle Race* (Appendix A-XV), they were motivated by the seemingly endless challenges that they placed on themselves, as one could always take it to the next level. For instance, once a group of students had built a slow car, they would change the gear train to make the car even slower. From my observations, motivation was most likely a result of the technology built into this unit. Students were challenged by the LEGO Mindstorms programming and were intrigued by what they could get their LEGO robots to do. Characteristic of a constructivist approach, students took an active and inquiry role in deciding how to apply the technology to produce their experimental goals.

Many students stated in their activity surveys (Appendix C-III and C-IX) that they understood or liked an activity because they could relate to the learning style of the activity. Based on these statements, I find the activities encouraged more and diverse learners by utilizing varied learning styles (Goodnough, 2001). Based on the descriptions of the intelligences as spelled out in the introduction of this paper, I was able to identify what types of learners my students were. Students who have a bodily/kinesthetic intelligence could actually feel the difference in mechanical advantage when working with the gear ratios. Those with the logical/mathematical intelligence gravitated towards the computer programming and enjoyed debugging the programs and dealing with technical difficulties. The use of visual/spatial intelligence in many activities appealed to many of the students. Visualization of concepts in real time captured my students' immediate attention and encouraged understanding. Based on my classroom observations, the constructivist approach and technology component of the activities prompted the student to work well as a team, and thus enhanced their interpersonal intelligence. From my observations, my classes' behaviors closely mirrored Meers' and Wiseman's study groups (Meers and Wiseman). Students who were more "applied" appeared to have higher bodily/kinesthetic abilities whereas students who were "theoretical" appeared to possess greater logical/mathematical skills. More of my students were "applied" than '"theoretical". This observation presents a good argument for using constructivism and technology in the science classroom.

The Student Unit Survey results (Appendix C-VIII) reveal that a science course can be made more captivating by integrating technology. The students' scoring of the helpfulness of constructivism to their learning is hard to interpret. Perhaps the students have trouble differentiating constructivist methods with other teaching methods. Students were given a rough idea of the constructivist approach at the beginning of the unit, however, it could have been introduced more concisely. I will explain and post a scale for analyzing the degree of constructivist learning in the classroom next year when I introduce constructivism. For the second semester group, the final project was a great example of combining constructivist techniques and technology to reinforce student learning. Finally, student indications that the unit was not easy to understand give mixed implications: students may find the unit challenging (a positive outcome), or students may find the unit to be too challenging (a negative outcome). As mentioned before, there were strong gains in the pre and post test data and positive student feedback from the student activities. This may suggest that the unit, despite its rigorous curriculum, provided students with a meaningful learning experience.

Unit Effectiveness

I believe that implementation of the new unit helped to solve some of the problems that I have encountered before the study. Some of the issues such as boredom, lack of ownership, lack of relevancy, and short term learning were resolved as students worked through the unit. This unit helped me to move my curriculum from a more content driven approach to that of a process driven one. This unit was more student centered than my previous unit on motion. My students did build on their previous knowledge especially as they worked through the activities that gave them more empowerment. The students became better problem solvers as a result of their activity experiences. Problem solving, in the concrete sense, became a natural course of action as students worked through robot design, using computer software, and modifying MBL technology to fit the objective of the activity. Students progressively improved on their problem solving abilities as they became familiar with the LEGO Mindstorms and MBL equipment. Additionally, their confidence level increased throughout the unit as they advanced in their abilities. Students made improvements in abstract problem solving as well, although the growth was not as strong for those who struggled with mathematics. The constructivist and technology methods of instruction oftentimes worked synergistically so that students were building knowledge while having fun in an efficient manner. The constructivist/technology combination allowed for an intellectually diverse group of learners to experience success in the science classroom.

I made modifications in the unit that I presented to the second semester group in order to improve the unit. It is difficult to use objective data to show that my modifications improved student performance from the first group to the second group. The two groups were too different, so I really had to make the comparisons subjective. Some labs were rewritten for clarity. For example, the *Determining Distance and Velocity* activity (Appendix A-II) originally had two methods of calculating velocity. It made more sense to the students when I narrowed the method down to one. I think this prevented students from getting too frustrated and distracted. Some labs were replaced with a different lab. I thought the *Rollercoaster* lab (Appendix A-XI) made much more sense to the students than the *Energy of the Swing* lab (Appendix A-X) did, as the scenario for the rollercoaster lab was more realistic. Adding the *Turtle Race* as a final project for the second semester group was a good review and a good way to finish the unit.

Some of the modifications evolved from the trial and error of teaching students the unit activities from day to day, from one group to the next group. Because there was so much group work involved in this unit, I became very aware of how to group students to create the best dynamics. Organization of the materials became extremely important, so I got better at planning ahead in the second semester. This allowed the second group to complete the unit in a more efficient and timely manner than the first group.

The unit still has some areas of weakness. The unit is extremely time intensive for both the teacher and the student. The MBL technology that I use in my classroom is aging and troubleshooting of equipment and repairs are becoming a hindrance to the learning process. The LEGO Mindstorms kits require some technical patience on the part of the teacher as well as the student. There are never enough computers available for programming the LEGO models. It is difficult to get a small percentage (around 5%) of students to take ownership of their work and respect the equipment. I attribute this to deeper issues within these students that prevent them from being able to engage themselves in a positive manner. These issues stem from unstable home lives and emotional problems. Some students who did not have a positive role model at home or did not know where they would be sleeping that night could not wholly engage themselves in an activity. Some "troubled" students find that they cannot maintain appropriate behavior for a whole school day. By fourth block, some of my students have already been sent to the dean with a discipline referral from another class. The complexity of the unit and expense of the technology equipment makes this unit easier to teach with a smaller group. The second semester group, with a class size of 19, was easier to work with than the first semester group of 25 students. Students need to be able to get feedback from the teacher during the activities and they need to have enough equipment to perform the activities.

The unit did meet most of my objectives. The primary objective of improving student understanding of motion by using a constructivist approach was met by most students. In addition, integration of LEGO Mindstorms and MBL technology into the unit made it more efficient and captivating. I would like to see if I can build more of an inquiry approach into the MBL activities. I will have students do a pre-lab prediction and post-lab prediction reflection for certain activities. Certain labs need to be modified in anticipation of my move into a new school building. The free fall experiment (Appendix A-VI) will be conducted from a 2nd floor balcony to allow for a greater number of data points and terminal velocity. In the interest of time constraints, some activities will be modified. For instance, *Acceleration, Part 1* (Appendix-IV) will be completed as a teacher demonstration. Activities such as *Energy of a Swing* (Appendix A-X) need to be rewritten for the sake of clarity. *Work and Power* (Appendix A-XII) needs directions for students to generate their own data table and calculations page. *Which machine is more efficient?* (A-XIII) needs a clear diagram for Part I, as students had trouble setting up the experiment from the instructions. I will continue to make my instructional delivery and individual student guidance more constructivist in approach in all of my classes. For example, I have to concentrate on using the Socratic method of answering student's questions with questions as a means to get the students to develop new information from previous knowledge. Another example is modifying problem solving exercises to make them more process focused.

A continued emphasis will be placed on teaching and maintaining reasonable student behavior in the classroom. As I mentioned before, 38.6% of my student had a cumulative first semester school average of below 60%. Again, about 5% of the students were difficult to engage in the activities. Although the constructivist approach is an excellent learning model, it does not work all the time for students who do not want to engage in the learning process. These students enjoyed the activities but had difficulties completing them and had trouble working with others. Students who were destructive and disruptive could not be allowed access to laboratory equipment. As a result, students were removed from the laboratory setting when they chose to been disruptive or destructive. Most students with low motivation had trouble working with others, initiating work, organizing materials, writing down data, and performing calculations. Grouping students to maximize positive group dynamics was difficult at times.

Ultimately, students with positive attitudes and participation achieved a greater increase in scores from their pre test to post test. These students did not hesitate to stay after school for extra help or to finish an activity. Some of these students were high ability students who wanted to fully understand what they were learning. Some of these students were students of average performance, but they needed some remedial help with concepts or math skills. Students who scored below average were the at risk students with positive attitudes, who still made gains (although smaller) from pre test to post test.

I am not sure how I will modify the unit to address students with behavioral issues. Perhaps teaching this unit at a later point in the semester, after some of the discipline problems are resolved, would help improve student behavior in the laboratory.

Having good classroom organization and teaching students to be more independent (find resources on their own, ask three students before they ask me, make decisions on their own, as examples) may give me more time next year to monitor and control negative student conduct. This last suggestion is my idea of maintaining a constructivist atmosphere while minimizing the disruptions that tend to undermine it.

Looking Beyond the Unit

This unit has opened my eyes by challenging me to take the constructivist approach to levels that I haven't before. I am using more constructivist strategies in my first year Chemistry classes (Chemistry I) and I am seeing positive results. When teaching chemical reactions, I had students perform demonstrationss to the ninth grade Physical Science classes. The Chemistry demonstration assignment required that they incorporate the constructivist strategies of using predictions and discrepant events in the delivery of their demos. As a result, their demonstrations had both educational and entertainment value. In the same course, I gave an end of the year lab assessment that required students to develop their own procedure for identifying the correct products in an acid/base reaction. Students had to perform the experiment and follow that up with a full lab report. This activity inspired a great deal of substantive conversation amongst the students. The open-endedness of the activity allowed for students of varying intelligences to achieve success.

In terms of technology, I would like to get more training in programming LEGO Mindstorms using the upgraded version of the programming software, Robolab 2.5. Robolab 2.5 software combines robot programming and built-in MBL technology.

Instead of using the MBL equipment to record motion data from the actions of the robots, motion data is collected, graphed infused and mathematically analyzed within the Robolab 2.5 software. In addition to motion, I would like to apply LEGO Mindstorms and Robolab 2.5 to the study of electricity, chemistry, and light.

Within the past year, I have challenged all of my Physical Science students by holding them to a level of intellectual accountability that I haven't in the past. From what I have witnessed, use of constructivist practices and technology integration improved student learning and student participation in motion. Constructivist strategies were gradually phased into all classes that I taught during the year and appeared to have positively affected student learning and student interest. To help students achieve success in the future, I will continue to place an emphasis on using constructivist strategies in my classroom. Additionally, I hope to find the LEGO Mindstorms /Robolab 2.5 combination to be a powerful instructional aid in the laboratory setting in the near future.

APPENDICES

APPENDIX A

(UNIT ACTIVITIES)

Appendix A-I

Lab:Determining Distance and Velocity

Problem: Program a wheeled robot to travel a linear path at a constant rate and stop precisely at the one meter mark.

Materials:

Robot
Legomindstorm programming software
Infrared Tower
Ruler
Masking Tape

Procedure:

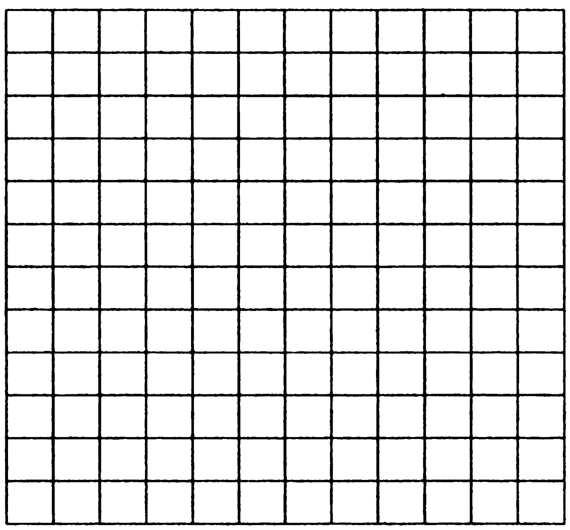
1. Program a robot to travel a straight line at a constant rate.

   Write down your program here:

2. Record the distance traveled every two seconds over a 10 second period.

Distance traveled (meters)	Elapsed Time (seconds)
	0
	2
	4
	6
	8
	10

3. Plot distance versus time. Distance should be in meters and time should be in seconds. Draw a best fit straight line through the plotted points.



4. Study your graph. How many seconds, to the nearest .1 s, should it take to travel exactly one meter? Explain.

5. What is the average velocity of the robot? (Hint: what is the formula for calculating average velocity?)

Appendix A-II

Lab: Interpreting Position vs Time Graphs

Objective: To graph time vs. position graphs from data and vice versa.

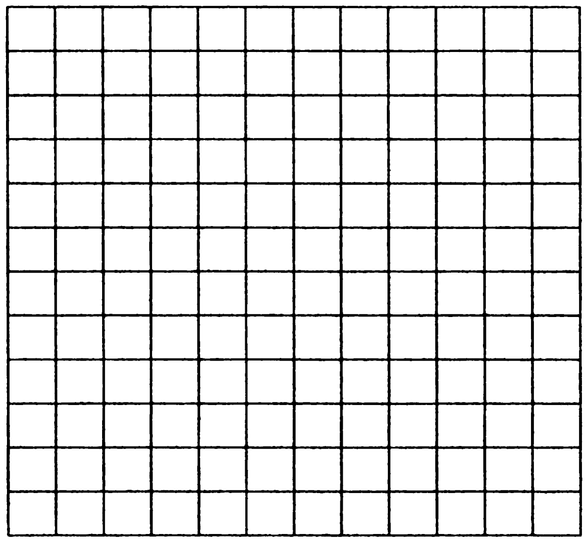
Materials: Lego robot with software setup
Meterstick
Vernier motion detectors/ CBL/calculator setup
Graph paper

Procedure:

Part 1: Graph the Path. Using motion detectors, students practice creating position vs time graphs from a teacher programmed path that the robot has taken.

1. Find a 4m long space and mark off each meter with a small piece of masking tape. Place the motion detector at the 0 meter mark.
2. Download the "path" program to your RCX box.
3. Position the robot 1 meter in front of the motion detector.
4. Press "run" on the robot.
5. Observe the path taken by the robot. Describe the robot's motion over time.

6. Roughly graph the path below by plotting distance vs. time. Label axes.



7. Use the CBL to verify your graph:

Download the *Physics with CBL* program from the teacher's computer to your TI-83 calculator using the Vernier software. Set up the calculator to run the motion detector.

a. SET UP PROBES, 1 probe, motion

b. COLLECT DATA, time graph, 1 second between samples, 20 samples

c.Use time setup, live display, Ymin= 0, Y max= 3, Yscl= .2

Position the robot 1m in front of the motion sensor. Press "run" on the robot while a lab partner presses "enter" on the calculator to begin collecting data. After the data is collected the graph should appear on the calculator screen. Continue to the next section.

Analysis:

1.) Does your approximate graph above match the graph on your calculator?

Check with the teacher to see if your graph is correctly drawn.

Teacher initials : _________

Part 2: Path the Graph. Given a specific position vs time graph, write a LEGO program for the robot to match it.

1. Write your program here:

2. Download your LEGO program to the RCX box on your robot.

3.Run the program on your robot.

4.Check your program: Does your robot's path match the graph? Use the motion detector program as you did in Part I of this lab to see if the calculator graph match's your teacher's graph.

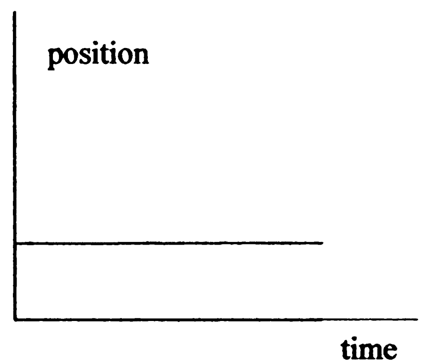
5. Demonstrate that your robot can "path the graph"

Teacher's initials of approval: ______________

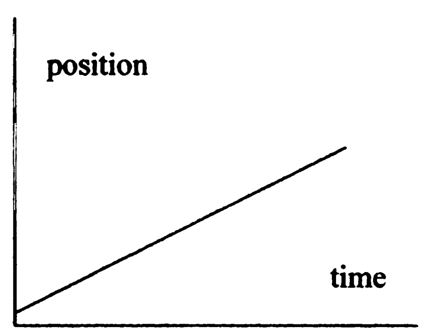
Homework: Position- Time Graphs

Place yourself as the object in each of these graphs. Answer the following questions to the right of each graph.

1. What are you doing to create this graph?



2. How do you walk to create a straight line that slopes up?



3. How do you walk so that the curve is steep at first and then continues up with a more gradual slope?

Appendix A-III

Lab: Velocity: Constant or Changing?

Velocity is the change in distance over time. It is important to distinguish the following terms: constant, instantaneous and average. Constant velocity is unchanging velocity. Instantaneous velocity is the velocity at a specific point in time. Finally, the average velocity indicates a distance traveled over a period of time. However, this does not provide information of how the velocity actually varies during that time interval.

In activity one, constant velocity was found by graphing distance vs. time. A straight line slope was generated from that data. Sketch the d vs. t graph of constant velocity here:

Let's change the power of the motors to gradually increase the speed of the robot going down a straight path:

1. Go to programs in the software and select from the small blocks the power block. Move that block to the starting positon of your program. Change the power from 8 to 1 by clicking on the right side of the block and making changes in that window.
2. Add a big block: forward, for 2 seconds.
3. Repeat with the power block, this time increasing by 1 unit. Follow with a forward block, 2 seconds.
4. Continue this process until the highest power value is obtained. Follow with a 2 second forward block.
5. The acceleration of the robot will be very subtle. You can test it by seeing how much slower it is compared to the time it takes to travel the same distance at a maximum power value of 8.

Graph the distance vs time for this robot run here:

Does this graph reveal a straight line slope? If not, why?

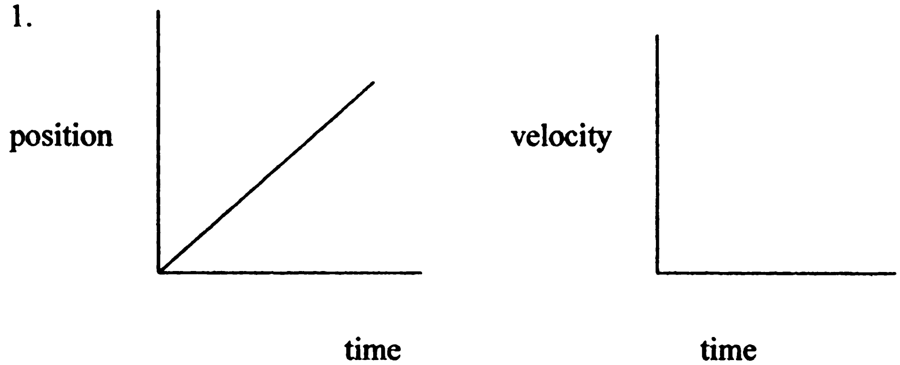
Graph velocity vs. time for the same robot run here:

Describe the slope of this curve:

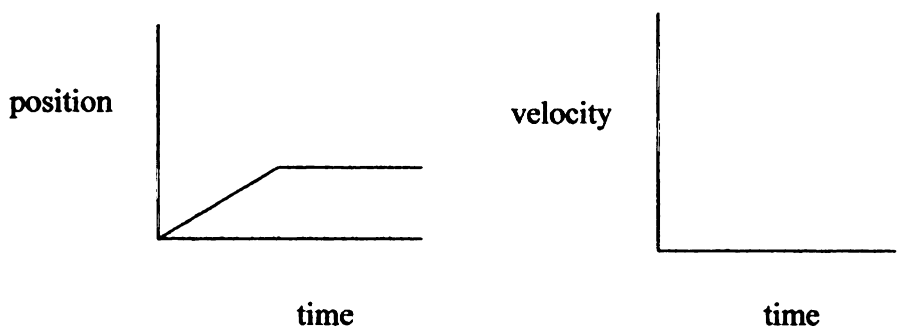
Homework Exercises

Draw velocity- time graphs for an object with position-time graphs as follows:

1.



2.



Appendix A - IV

Lab: Acceleration

Objective: To construct the meaning of acceleration. To graph velocity vs. time as a means of arriving at acceleration. To compare two methods of calculating acceleration.

Part I. Using Photogates to measure acceleration

Materials: dynamics cart and track, dual photogate timer, CBL, TI 83 calculator, 3x5 card, tape

How a photogate acts as a timer: The photogate has a narrow infrared beam that travels from the source to the detector. When a photogate is blocked, the output of the photogate is low, and the LED on the sensor turns on. When the photogate is unblocked, the output of the photogate is high, and the LED turns off. Sending an object through a photogate allows the program to record the length of time that the photogate is blocked. Knowing the length of the object and the time it blocks the photogate provides data for the calculation of instantaneous velocity.

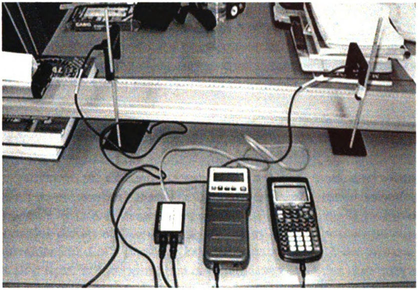
Pre Lab Photogate Practice:

Calculating instantaneous velocity using 1 photogate.

Physics Program
Main menu
Set up probes, number of probes-1
Select Probe, photogate, connect to channel 1
Timing mode, gate, number of gates-1
Arm CBL
Send object through photogate

Length of object traveling through photogate = ______m
Time required for object to travel through photogate = ______ s
Velocity of object traveling through photogate = ______m/s

Set Up Dual photogate track as shown:
Position the height of the ramp 5 to 10 cm above the table.



One way to calculate the average acceleration of the cart is to measure an initial and a final velocity over a certain time interval. Acceleration is therefore the change in velocity over time, or

$$a = (v_f - v_i)/\Delta t$$

We know from the photogate practice how to measure v_i and v_f, but how do we find the time required to travel from gate to gate, Δt? The following command on your TI-83/CBL Physics program allows you to calculate this: Timing mode, pulse.

The pulse function allows you to measure the time elapsed between blocking the first a second gates.

Data:

Length of card (d)		m
$Time_1$ (t_1)		s
$Time_2$ (t_2)		s
Pulse (Δt)		s

Show calculations for acceleration here:

$v_1 =$
$v_2 =$
$a =$

Part II. Using the motion detector to measure acceleration (modified from Physics with CBL, expt.3)

Accelerated Motion

For the special case of motion along a line, which you will explore in this experiment, the direction is indicated by the algebraic sign of the acceleration. That is, the acceleration can either be positive (in the direction of increasing positive distances from the origin) or negative (in the direction of decreasing positive distances from the origin). Most of the motions you experience involve acceleration. Let's consider a car traveling in increasing positive distances from a stop sign. While riding in a car that leaves from the stop sign, you undergo a positive acceleration. Later, as the car slows to a stop, you experience a negative acceleration. When a car picks up speed constantly, it undergoes *uniform* acceleration. In this experiment, you will collect and analyze distance and velocity data for a cart as it accelerates down a ramp.

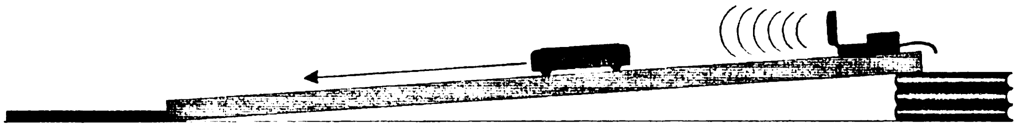


Figure 1

OBJECTIVES

- Use a Motion Detector to collect distance and velocity data as a cart accelerates down an incline and then rolls to a stop.
- Analyze graphs of distance *vs.* time and velocity *vs.* time for accelerated motion.
- Determine the mathematical relationship between the velocity and time for this motion.
- Determine the mathematical relationship between the distance and time for this motion.

MATERIALS

TI-83 or TI- 83 Plus	ramp
CBL System	dynamics cart
Vernier Motion Detector	books
PHYSICS program loaded on calculator	carpet square

PRELIMINARY QUESTIONS

Answer the following questions on a separate sheet of paper. The first four questions relate to a car uniformly accelerating from rest for 10 seconds.

1. How would the car's velocity after four seconds compare to its velocity after two seconds? How would its velocity at ten seconds compare to the velocity at two seconds?
2. Sketch a velocity *vs.* time graph of the car as it uniformly picks up speed. Describe in words what this graph means.
3. Would the car cover more distance over the first two seconds of acceleration or the last two seconds?
4. Sketch a graph of the distance *vs.* time as the car accelerates. Describe in words what this graph means.
5. Sketch a velocity *vs.* time graph of a car as it slows down uniformly. Describe in words what this graph means.
6. Sketch distance *vs.* time graph as a car slows down and finally stops. Describe in words what this graph means.

☺ Check answers with the teacher before continuing on
________________________ (teacher initials)

PROCEDURE

1. Place two or three books under one end of a 1.2 – 3 m long board or track so that it forms about a 5° angle with the horizontal. Place the carpet square at the bottom of the ramp so that the cart will roll off the ramp onto the carpet.
2. Place the Motion Detector at the top of an incline.
3. Connect the Vernier Motion Detector to the SONIC port of the CBL unit. Use the black link cable to connect the CBL unit to the calculator. Firmly press in the cable ends.

4. Set up the calculator and CBL for the Motion Detector. Start the PHYSICS program and proceed to the MAIN MENU.

- Select SET UP PROBES from the MAIN MENU.
- Select ONE as the number of probes.
- Select MOTION from the SELECT PROBE menu.

5. Set up the calculator and CBL for data collection.

- Select COLLECT DATA from the MAIN MENU.
- Select TIME GRAPH from the DATA COLLECTION menu.
- Enter "0.05" as the time between samples, in seconds.
- Enter "80" as the number of samples (the CBL will collect data for about 4 seconds).
- Press (ENTER), then select USE TIME SETUP to continue. If you want to change the sample time or sample number, select MODIFY SETUP instead.

6. Hold the cart on the incline about one meter from the bottom of the ramp and at least 0.5 m from the Motion Detector.

7. Press (ENTER) to begin collecting data. After the Motion Detector starts to click, hold the cart for about one second, then release it. Get your hand out of the Motion Detector path quickly.

8. Select DISTANCE from SELECT GRAPH menu. Examine the distance *vs.* time graph. Repeat Steps 6 and 7 if your distance *vs.* time graph does not show areas of smoothly changing distance. Check with your teacher if you are not sure whether you need to repeat the data collection. To repeat data collection, press (ENTER) to return to the SELECT GRAPH menu; select YES from the REPEAT? menu.

9. Answer the Analysis questions

DATA TABLE

	Time(s)	Velocity (m/s)	ΔVelocity(m/s)	Δ Time (s)	Avg. accelerat-ion (m/s^2)
Speeding up begins					
Speeding up ends					

Linear curve fit for velocity data (y = AX + B)	

ANALYSIS

1. Either print or sketch the distance *vs.* time graph. The graph you have recorded contains regions for each part of the motion. It is important to identify these regions. **Record your answers directly on the printed or sketched graph.**

   a) Examine the distance *vs.* time graph and identify when the cart was initially at rest on the ramp. **Label this region on the graph.**

   b) Identify when the cart was accelerating down the ramp. **Label this region on the graph.**

   c) Identify when the cart was slowing to a stop. **Label this region on the graph.**

   d) Is the cart moving in the direction of increasing or decreasing distance from the origin as it rolls down the ramp? How can you tell?

2. View the velocity *vs.* time graph by pressing (ENTER) to return to the SELECT GRAPH menu and selecting VELOCITY. Either print or sketch the graph. The graph you have recorded contains regions for each part of the motion. It is important to identify these regions. **Record your answers directly on the printed or sketched graph.**

   a) Examine the velocity *vs.* time graph and identify when the cart was initially at rest on the ramp. **Label this region on the graph.**

   b) Identify when the cart was accelerating down the ramp. **Label this region on the graph.**

   c) Identify when the cart was slowing to a stop. **Label this region on the graph.**

3. Determine the acceleration of the cart on the ramp using the velocity graph. Use the cursor keys on the velocity *vs.* time graph to read numeric values:

a) On the graph, locate when the cart began to accelerate down the ramp. **Record the beginning time and velocity in the Data Table.**

b) Use the cursor keys to determine when the cart stopped its uniform acceleration. **Record the ending time and velocity in the Data Table.**

c) Calculate the change in velocity (Δ velocity) and the corresponding change in time (Δ time) and **record your results in the Data Table.**

d) Calculate the acceleration and **record your results in the Data Table.**

4. To examine the positive acceleration more closely, you need to first remove the data that do not correspond to the cart freely rolling down the ramp.

- Proceed to the MAIN MENU.
- Select ANALYZE from the MAIN MENU.
- Select SELECT REGION from the ANALYZE MENU.
- Select VELOCITY from the SELECT GRAPH menu.
- Using the cursor keys, move the lower-bound cursor to the point when the cart first began to accelerate.
- Press (ENTER) to record the lower bound.
- Using the cursor keys, move the upper-bound cursor to the point when the cart stopped accelerating uniformly.
- Press (ENTER) to record the upper bound.
- After the selection is complete, the SELECT GRAPH menu will appear. Select VELOCITY from the SELECT GRAPH menu. You will see the selected portion of your graph filling the width of the screen.
- Print or sketch this graph.
- Describe the graph in words.

5. Each of these graphs can be modeled with a function. The graph of velocity *vs.* time should be linear. The calculator can fit a linear function to these data.

- Proceed to the MAIN MENU.
- Select ANALYZE from the MAIN MENU.
- Select CURVE FIT from the ANALYZE MENU.
- Select LINEAR L1, L5 from the CURVE FIT menu.
- **Record the parameters of the linear curve fit in the Data Table.**

6. How closely does the coefficient of the x term in Step 5 compare to the acceleration you calculated in Step 3?

7. Are the calculations for acceleration similar in Parts I and II of this lab?

Lab: Free Fall (See Physical Science with CBL, Experiment 40)

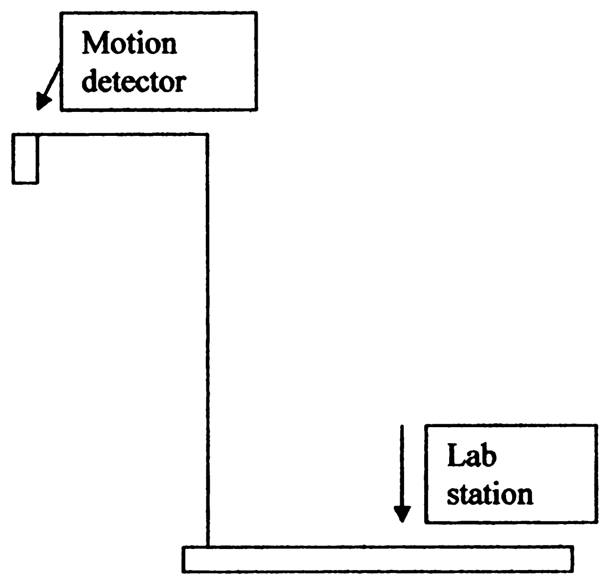
Purpose: To investigate acceleration due to gravity. To determine the meaning of terminal velocity. To construct force diagrams which provide a visual explanation for the differences in acceleration seen in the presence of air resistance.

Materials:

CBL	metal rod that mounts into lab station
TI graphing calculator	crossbar
Vernier Motion Detector	right angle clamp
	basket coffee filter
	meter stick

Procedure:

1.Set up the apparatus as shown:



2. Connect the motion detector to the Sonic Channel of the CBL. Connect the CBL to the TI calculator with the link cable.
3. Turn on the CBL unit and the calculator. Press PRGM and select PHYSICS. Press ENTER, then press ENTER again to go to the MAIN MENU.
4. Set up probes:
   - Select SET UP PROBES from the MAIN MENU
   - Enter "1" as the number of probes.
   - Select MOTION from the select probe menu.

5. Set up data collection:
   - Select COLLECT DATA from the MAIN MENU.
   - Select TIME GRAPH from the DATA COLLECTION menu.
   - Enter "0.25" as the time between samples, in seconds.
   - Enter "12" as the number of samples.
   - Press ENTER, then select TIME SETUP
   - Press ENTER, then select LIVE DISPLAY.
   - Set Yaxis: Y min = 0, Y max = 3, Y_{scale} = 1

6. Data collection:
   - Hold a coffee filter with the open side facing up, at a position .5m below the motion detector.
   - Press ENTER to begin collecting data.
   - Start dropping the coffee filter when you first hear the clicking from the detector.
   - Select NO at the REPEAT? prompt when you are satisfied with your data.

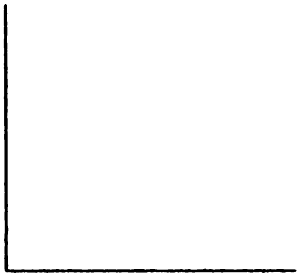
7. Study the distance vs time graph.
   - Press ENTER, then select ANALZE in the main menu.
   - Select VIEW GRAPH to display the graph.
   - Study this graph and draw your graph in the space provided in the data section.
   - Move the cursor to the drop point on your display. Record the coordinates (time in x, distance in y) for that point in your data section. Do the same for the landing point.

8. Study the Velocity vs Time graph
   - Select ANALYZE at the MAIN MENU.
   - Select VIEW GRAPH
   - Select VELOCITY. Examine the velocity vs time graph. Sketch the graph in the space provided in your data section. MAKE SURE THE AXES ARE CORRECTLY LABELED.
   - Move the cursor to the drop point on your display and record the coordinates (time in x, velocity to the nearest .01 m/s in y). Do the same for the landing point.

9. Collect data for a falling book.
   - Repeat Procedure 5-8 using a book.

Data

Falling Coffee Filter



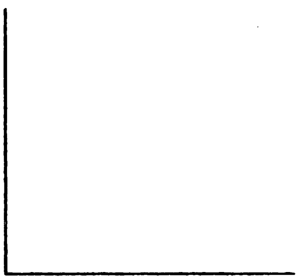
distance vs. time

velocity vs time

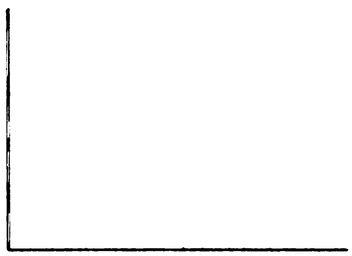
(x) (y)

Drop point ________s ___________m
Landing point ______s ___________m
Falling time ____________s (how long did it take from drop to landing?)
Distance traveled ________m (what is the total distance from drop to landing?)
Average velocity ___________m/s (what is the distance traveled in the falling time?)

Falling Book



distance vs time



velocity vs time

(x) (y)

Drop point ________s ___________m
Landing point ______s ___________m

Falling time ____________s
Distance traveled ________m Average velocity __________________ m/s

Analysis:

1. Which object had a higher average velocity? Explain.

2. Which object encountered more air resistance? Explain.

3. An object that falls at a constant speed is said to have reached *terminal velocity*. Study the two velocity vs. time graphs and comment on whether either object reached terminal velocity.

Appendix A-VI

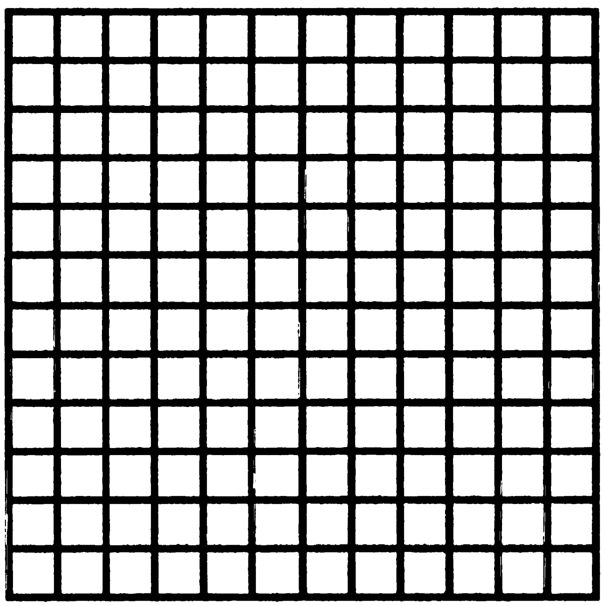
Lab: Vector Addition

Objective: To learn how to add vectors to find the resultant vector.

Procedure:

1. Program your robot to travel from the starting position to the target in four consecutive straight line movements.
2. You can only use the forward block and make right angle turns.

- Using solid lines for vectors, graph your path using the vector addition method.
- Using a dotted line, draw in the resultant vector .



3. Program your robot to travel from start to finish using one forward block.
4. Run the program to see if your prediction matches the actual run (does your robot end up at the target?

Appendix A-VII

Newton's Laws Demos

Demo 1. Crash Test Barbie (Newton's first law, from Conceptual Physics Lab #9: Buckle Up!)

An object in motion stays in motion until acted upon by an outside force. This resistance to change in motion is called *inertia.*

Crash test #1: Set up a cart on a ramp with a pulley attached to a weight. Set a wooden block at the end the the ramp to catch the cart. (let weight down, car moves down ramp until the wooden board stops it)

Crash test #2: Set up a cart on a ramp, as in Crash test #1. This time, seat a Barbie doll on the cart. Release the doll/cart (car stops, Barbie continues forward)

Crash test #3: Set up a cart on the ramp as in Crash test #2. This time, seatbelt Barbie to the cart. (Car and Barbie are both stopped by the wooden board)

Demo 2. Does mass affect acceleration due to gravity? (J. Gartrell)

Place two small marbles of the same size side by side at the top of two adjacent inclines (propped up by two textbooks). Watch the two marbles hit the text at the end of the ramp simultaneously. Do the same demo, except replace one of the marbles with a large marble. Does mass affect gravitational acceleration?

Demo 3. F= ma? (P. Robinson)

Acceleration vs. mass-
Using a spring scale, pull a smaller person on roller blades with a constant force. Observe the acceleration. Now repeat the experiment with a larger person. How is the acceleration affected by the mass?

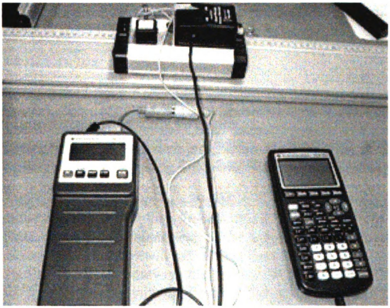
Acceleration vs force-
Using a spring scale, pull a smaller person on roller blades with a constant force. Now repeat the experiment, pulling with a greater force. How is the acceleration affected by the exerted force?

Appendix A – VIII

Activity #8: Constructing Newton's Second Law
(adapted from Physics with CBL, expt. 9)

How does a cart change its motion when you push and pull on it? You might think that the harder you push on a cart, the faster it goes. Is the cart's velocity related to the force you apply? Or does the force just *change* the velocity? Also, what does the mass of the cart have to do with how the motion changes? We know that it takes a much harder push to get a heavy cart moving than a lighter one.

A Force Sensor and an Accelerometer will let you measure the force on a cart simultaneously with the cart's acceleration. The total mass of the cart is easy to vary by adding masses. Using these tools, you can determine how the net force on the cart, its mass, and its acceleration are related. This relationship is Newton's second law of motion.



OBJECTIVES

- Collect force and acceleration data for a cart as it is moved back and forth.
- Compare force *vs.* time and acceleration *vs.* time graphs.
- Analyze a graph of force *vs.* acceleration.
- Determine the relationship between force, mass, and acceleration.

MATERIALS

TI-82, 83, 86, 89, 92, or 92 Plus	PHYSICS program loaded in calculator
CBL System	low-friction dynamics cart
Vernier Force Sensor	0.50-kg mass
Vernier Low-g Accelerometer	Vernier adapter cables (2)

PRELIMINARY QUESTIONS

1. When you push on an object, how does the magnitude of the force affect its motion? If you push harder, is the change in motion smaller or larger? Do you think this is a direct or inverse relationship?

2. Assume that you have a bowling ball and a baseball, each suspended from a different rope. If you hit each of these balls with a full swing of a baseball bat, which ball will change its motion by the greater amount?

3. In the absence of friction and other forces, if you exert a force, *F*, on a mass, *m*, the mass will accelerate. If you exert the same force on a mass of 2*m*, would you expect the resulting acceleration to be twice as large or half as large? Is this a direct or inverse relationship?

PROCEDURE

1. Connect the Low-g Accelerometer using the adapter cable to CH1 of the CBL System. Connect a Student Force Sensor or Dual-Range Force Sensor using the adapter cable to CH2 of the CBL System. If you are using a Dual-Range Force Sensor, set the range switch to 50N. Use the black link cable to connect the CBL System to the TI Graphing Calculator. Firmly press in the cable ends.

2. Attach the Force Sensor to a dynamics cart so you can apply a horizontal force to the hook, directed along the sensitive axis of your particular Force Sensor. Next, attach the Accelerometer so the arrow is horizontal and parallel to the direction that the cart will roll. Orient the arrow so that if you *pull* on the Force Sensor the cart will move in the direction of the arrow. Using a spring scale, find the mass of the cart with the Force Sensor and Accelerometer attached. Record the mass in the Data Table.

3. Turn on the CBL unit and the calculator. Start the PHYSICS program and proceed to the MAIN MENU.

4. Set up the calculator and CBL for the Force Sensor and the Accelerometer.

- Select SET UP PROBES from the MAIN MENU.
- Select TWO as the number of probes.
- Select ACCELEROMETER from the SELECT PROBE menu.
- Confirm that the Accelerometer is connected to CH 1, and press ENTER.
- Select USE STORED from the CALIBRATION menu.

- Select LOW-G from the ACCELEROMETER menu.
- Select FORCE from the SELECT PROBE menu.
- Select DUAL RANGE 50 N as appropriate for your sensor.
- Confirm that the Force Sensor is connected to CH 2, and press ENTER.
- Select USE STORED from the CALIBRATION menu.

5. Next you will zero the sensors. To do this, place the cart on a level surface.

- Select ZERO PROBES from the MAIN MENU.
- Select ALL CHANNELS from the SELECT CHANNEL menu.
- With the cart stationary and no force applied to the Force Sensor, wait for the reading on the CBL to stabilize, and then press TRIGGER on the CBL.

6. Set up the calculator and CBL for data collection.

- Select COLLECT DATA from the MAIN MENU.
- Select TIME GRAPH from the DATA COLLECTION menu.
- Enter "0.1" as the time between samples, in seconds.
- Enter "50" as the number of samples (the CBL will collect data for about 5 seconds).
- Press ENTER, then select USE TIME SETUP to continue. If you want to change the sample time or sample number, select MODIFY SETUP instead.

Trial I

7. You are now ready to collect force and acceleration data. Grasp the Force Sensor hook. Press ENTER and take several seconds to *gently* move the cart back and forth on the table. Vary the motion so that both small and moderate forces are applied. Make sure that your hand is only touching the hook on the Force Sensor and not the Force Sensor itself or the cart body.

8. Press ENTER to see the first graph of acceleration *vs.* time and sketch the graph in your notes. Press ENTER again to see the force *vs.* time graph, sketching it the same way. How are the graphs similar? How are they different?

9. One way to see how similar the acceleration and force data are is to make a new plot of force *vs.* acceleration, with no time axis.

- Press ENTER and select NO to return to the MAIN MENU.
- Select ANALYZE from the MAIN MENU.
- Select CURVE FIT from the ANALYZE MENU.
- Select LINEAR L2 , L3 from the CURVE FIT menu.
- Record the parameters of the fitted equation your Data Table.
- Press ENTER to see your force *vs.* acceleration plot with the fitted equation.
- Print or sketch your graph.
- Press ENTER to return to the MAIN MENU.

10. Using the regression equation, determine the acceleration of the cart when a force of 1.0 N has acted upon it. Record the force and acceleration in the Data

Table.

11. Repeat Step 10 using a force of –1.0 N.

Trial 2

12. Attach the 0.50-kg mass to the cart. Record the mass of the cart, sensors, and additional mass in the Data Table.

13. Repeat Steps 6 – 11.

DATA TABLE

Trial I

Mass of cart with sensors (kg)	

Fitted equation for force *vs.* acceleration data

Trial 2

Mass of cart with sensors (kg)	

Fitted equation for force *vs.* acceleration data

ANALYSIS

1. Compare the graphs of force *vs.* time and acceleration *vs.* time for a particular trial.

2. Are the net force on an object and the acceleration of the object directly proportional? Explain, using experimental data to support your answer.

3. What are the units of the slope of the force *vs.* acceleration graph? Simplify the units of the slope to fundamental units (m, kg, s).

4. For each trial compare the slope of the regression line to the mass being accelerated. What does the slope represent?

5. Write a general equation that relates all three variables: force, mass, and acceleration.

APPENDIX A-IX

Lab: Newton's Third Law: Action and Reaction

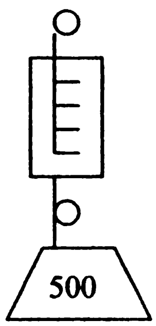
(See Conceptual Physics Lab Manual, Experiment 18.)

According to Newton's Third Law, for every action there is an equal and opposite reaction. What does this statement really indicate in our everyday interactions? In this lab, you will discover for yourself the concept behind balanced pairs of two interacting forces.

Materials: Two 500g weights, 2 spring scales, 2 ring stands, books for support, string.

Part A. Suspend a 500g weight from a string to the end of a spring scale. (see Fig.A)

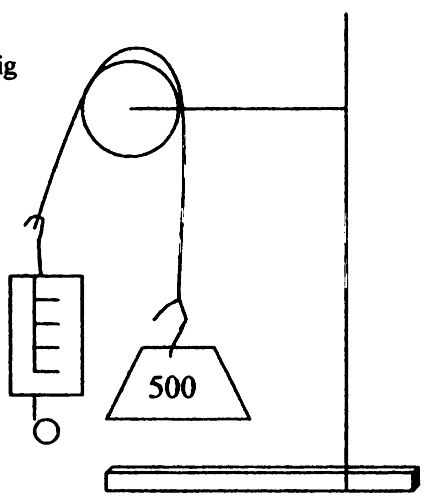
Fig A



1. How does the tension in the string compare to the weight of the load?
2. Draw a force diagram of this set up.

Part B. Suspend a weight hanging from a string by threading the string through the pulley. Attach the end of the spring scale to the end the the string. Hold the spring scale downwards and keep the force steady. (see Fig.B)

Fig B

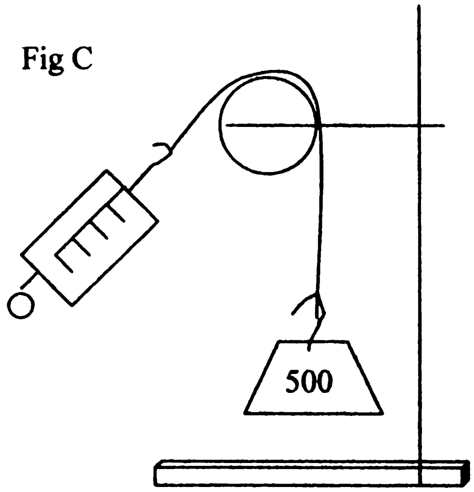


3. Record the force measured by the scale. How does this measurement compare to the weight of the load?
4. How does the measurement compare with the tension in the string?
5. Draw a force diagram of this set up.

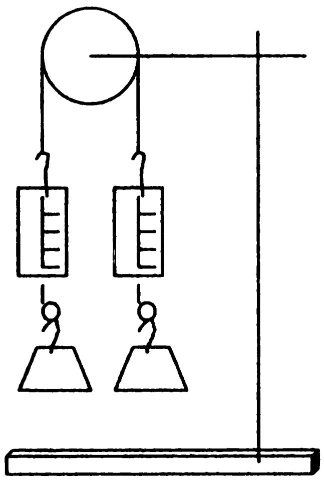
Part C.

Keep the set up as in Part B, but change the distance of the scale from the table. (see Fig. C)

Fig C



6. How does this affect the scale reading? Explain your result.



Part D.

Attach a spring scale to each end of the string. Drape the string over the pulley and attach equal masses to each end, as shown in Figure D.

7. What do the scales read?
8. Draw a force diagram of this.

Fig D

Part E. Have your partner hold one end of the spring scale while you pull horizontally on the other. Pull until you have the same force reading as the force exerted by the load in Part A.

Force you exert on the scale = ______________________________

Force the scale exerts on you = ______________________________

Force your partner exerts on the scale = ______________________

Force the scale exerts on your partner = _______________________

Part F. Tie one end of the spring scale to the wall with a string. Pull on the other end of the spring scale with the same force as in Part E.

Force you exert on the scale = ________________________________

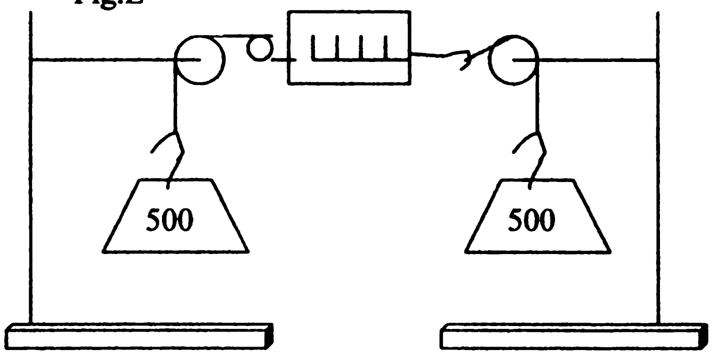
Force the scale exerts on you = _______________________________

Force the string exerts on the wall = ___________________________

Force the wall exerts on the string = _____________________________

Part G. Study Figure E and, based on what you see in Parts E and F, predict the scale reading when two 500g loads are placed on either end of the strings.

Fig.E



Predicted scale reading = ___________________

Actual scale reading = _____________________

9. Draw a force diagram showing each of the forces involved in the set up in Figure E.

10. How are Part E, F, and G similar?

Appendix A-X

<u>Lab: Energy of a Swing </u>(See Glencoe, *Physical Science*, pp 132-133)

Scenario: You are swinging in a swing. What would happen if a friend tried to stop you by grabbing the swing's chains halfway up as you passed the lowest point? Would you come to a complete stop or continue rising to your previous maximum height?

Problem: How can you create a model to answer the questions above?

Hypothesis: What will happen to the pendulum's motion and final height if its swing is interrupted by the crossarm?

Procedure:

You must include these items in your procedure:

- **Draw a diagram of the setup**
- **Construct a pendulum to compare the transfer of potential and kinetic energy when a swing is interrupted.**
- **Measure starting and ending heights of the pendulum swing.**
- **Include three trials**

Diagram:

Data Table:

Analysis:

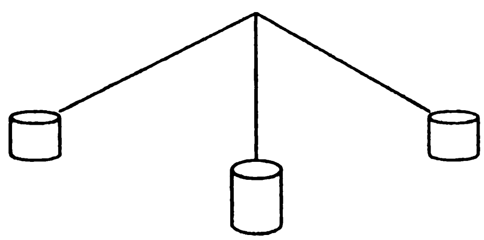
1. When the stopper is released from the same height as the crossarm, is the ending height of the stopper exactly the same as the starting height?

2. Predict what will happen to the ending height if the starting height is higher than the crossarm.

3. Are the starting and ending heights the same? How can you explain your observation?

4. Take a close look at the energy transfers.

- Label the point on the swing below when the stopper has the greatest kinetic energy with the symbol KE_{max}. (Hint: Where is the stopper traveling at the greatest speed?)
- Label the point with the greatest potential energy with the symbol PE_{max}. (Hint: Where is the stopper traveling with the slowest speed?)



Conclusion: (Now go back to the beginning of the lab to see if your data matches with your hypothesis.)

Appendix A-XI

Lab: Rollercoaster!

Purpose: To design a model rollercoaster. To analyze the motion and energy of a marble as it travels down the model rollercoaster.

Rules:
1. You will work with your assigned partner(s).
2. All construction must be done in class during regular class time.
3. You can only use approved materials provided.
4. All items must be kept in a labeled bag.

Grading: Your coaster will be graded from the following checklist:

Specifications:

__ Height under 1 meter (5)
__ Length under 1 meter
__ Freestanding on a base (must be able to move coaster)
__ Contains a loop or corkscrew turn
__ Includes a second level — Total Points = ___/25

Track Performance:

__ Marble rides entire track safely
__ Marble causes another action to occur after it leaves the track — Total Points = ___/20

Individual Notebooks:

__ Sketch of Coaster (10)
__ Physics of Coasters Question and Answer Sheet (10)
__ Daily Journal (10) — Total Points = ___/30

Final Grade= ___/75

Physics of Rollercoaster Question and Answer Sheet
**show formulas and data for all calculation questions*

1. *Calculate the work done to bring the marble to the start of the ride.*

2. *Where on the ride does the marble have maximum potential energy?*

3. *Where on the ride does the marble have maximum kinetic energy?*

4. *What happens to the marble's kinetic energy as it goes up a hill and slows down?*

5. *Would a marble ever be able to get over a hill higher than its initial starting height?*

6. *How would using a different sized marble affect its initial potential energy?*

7. *Calculate the maximum potential energy of the marble*

8. *Assume that there is no friction on the track and all potential energy is converted to kinetic energy. Based on this assumption, calculate the maximum kinetic energy of the marble.*

9. *Based on the calculated maximum kinetic energy in #8, solve for the maximum speed of your marble rider.*

10. *Calculate the maximum momentum of your marble rider.*

Appendix A –XII

<u>Lab: Work and Power (adapted from *Physical Science*, Glencoe)</u>

Objective: To calculate how much power a car has.

Materials: ramp, "pull back" car, timer, ruler

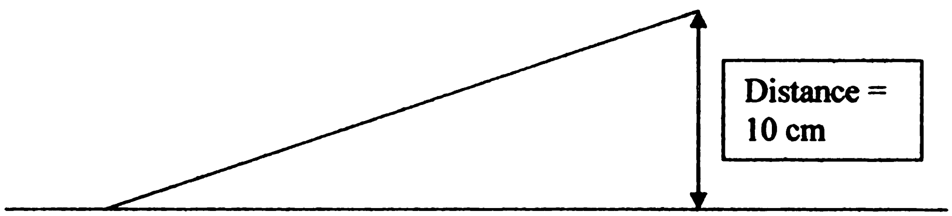
Procedure:

Part A: Power on a Ramp

1. Record the mass of the car in kg by using a spring scale.
2. Weight is the gravitational influence on an object's mass. Calculate the weight of the car. Weight is also known as the force due to gravity. The unit for force is Newtons, or N.

Weight = $\textbf{Force}_{\textbf{gravity}}$ = mass, in kg x 9.8 $\textbf{m/s}^2$

3. Position the ramp 10 cm above the table. This height represents the distance that the car travels vertically.



4. Work is the weight of the object exerted over the distance in the direction of the applied force. Calculate work done by the car motor on the car.
Work = Force x distance **(work is measured in Joules)**

5. Record the time it takes for the car to get to the top of the incline.
   Note: It is important to keep the start position and amount "pull back" constant.

   Time is measured in seconds.

6. Calculate the power of the car motor. Power is the rate at which work is done. If the car has more speed, it has more power.

   Power = Work/time

   (power is measured in J/s, and this unit is call a Watt)

Part B. Robot Power

What is the power of your robot? Calculate the robot's minimum power and maximum power in Watts.

1. Program your robot to go forward at minimum power setting.
2. Use the procedure from step A as a process for calculating your robot's minimum power.
3. Repeat 1-2, using the maximum power setting.

Appendix A-XIII

Lab: Which machine is more efficient?

Objective: To see how a machine changes the amount of force required to do work on a mass. To measure the efficiency of a machine and compare machine efficiencies.

Background Reading: Glencoe, Physical Science, pp 186-194)

Part I. Efficiency of an Incline (Introduction to Mechanics, Book Two)

Materials: 1.3 m smooth ramp, cart, spring scale, text books

Procedure:

1. What is the force required to move the cart to a height of 20 cm without the aid of the incline? This is the value for $force_{out}$. Record the value.
2. Make a stack of books 20 cm high. Record this as the $distance_{out}$.
3. Prop the ramp on the books so that the 90 cm mark on the ruler is above the support point on the top of the stack of books.
4. Tape a ruler along the edge of the ramp, with 0 cm mark at the starting point.
5. Pull the cart up the ramp at a constant velocity with a spring scale. Record the force in Newtons required to pull the cart up the ramp.
6. Next, move the ramp so that the 75 cm mark is above the support point on the top of the stack of books.
7. Repeat Step 3 of the procedure.
8. Move the incline again, with continued force readings at 60, 45, and 30 cm marks. Record the force reading in the data table below.
9. Calculate the $work_{in}$ and the % efficiency in each trial and record results in the data table.

Data and Calculations:

$Force_{out}$ = ______________________

$Distance_{out}$ = ____________________

$Work_{out} = Force_{out} \times Distance_{out}$ ________________________

Point of Support (cm)	Force $_{in}$	Distance$_{in}$	Work$_{in}$ (F_{in} x d_{in})	%Efficiency (W_{out}/Win) x 100
90				
75				
60				
45				
30				
				Average=

From the data and calculations recorded in the table above, answer these questions:

1. Does it take more or less force to move the cart using the inclined plane?

2. Does it take more or less work to move the cart using the inclined plane?

3. How does changing the slope of the inclined plane change the force required to pull the cart up the ramp?

4. Calculate the % efficiency of the slope, using (AMA/IMA) x 100

Part II. Efficiency of a Pulley(Holt, Physics)

Procedure

1. Set up a pulley system as shown
2. Align the weight being pulled (force$_{out}$) with a reference point on the ruler. Record initial position of force$_{out}$.
3. Record initial position of force$_{in}$. Add counterweights to the pulling weight (force$_{in}$) until the weight begins to move at a constant velocity.
4. Record force$_{out,}$ force$_{in}$, final positions of force$_{in}$ and force$_{out}$.

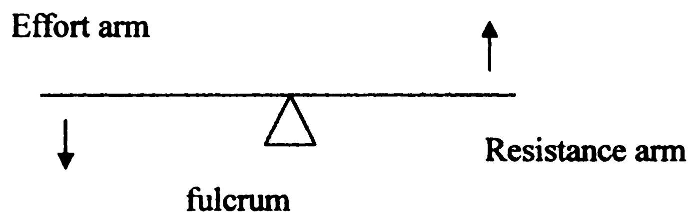
Data:

Force in	Force out	Δd_{in}	Δd_{out}

Calculations:

Work in	Work out	% efficiency

Part III. Efficiency of a Lever



Procedure:

1. Suspend a ruler from the central fulcrum as indicated.
2. Hang a weight at one end. This is $force_{out}$. Record $force_{out}$ in Newtons, and measure and record distance of weight from fulcrum (this is the length of the lever arm, d_{out}).

3. Place a counterweight on the other side of the fulcrum and move the weight along the ruler until the lever is balance. Record the weight of the counterweight ($force_{in}$). Measure and record the distance of this lever arm, d_{in}.

4. Calculate work and %efficiency. Record in calculations table below.

Data:

Force in	Force out	Δd_{in}	Δd_{out}

Calculations:

Work in	Work out	% Efficiency

5. Solve for the efficiency of this lever by using (AMA/IMA) x 100

Questions:

1. Compare the efficiency values of the incline, pulley, and lever machines in this lab. What causes these differences in values?

2. You calculated the efficiency of each machine using two different formulas. Were the efficiency values the same for a particular machine? Comment on the accuracy of your results.

Appendix A-XIV

Lab: Gear Ratios (Glencoe, Physical Science lab manual, Expt. 16)

Purpose: To examine the mechanical advantage of different gear combinations.

Materials: Lego gears, gear chains, bricks with holes, axles, connector peg with axle.

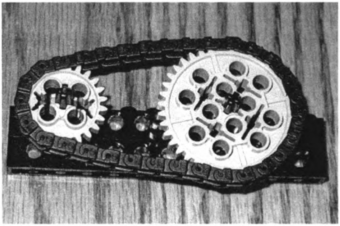
Formulas:

Mechanical advantage MA= # teeth on rear gear/ # teeth on front gear

Speed advantage = SA = #teeth on front gear/ # teeth on rear gear

Procedure:

1. Construct a gear combination with two gears as shown. Add the gear chain.



2. Turn the "pedal" with one hand and observe the relative speed of the rear wheel.
3. Count the number of teeth in the front gear. Record in data table. Do the same for the rear gear.
4. Repeat steps 1-3, varying the size of the front gear.

Data:

# teeth on front gear	# teeth on rear gear	Mechanical Advantage (MA)	Speed Advantage (SA)

Analysis:

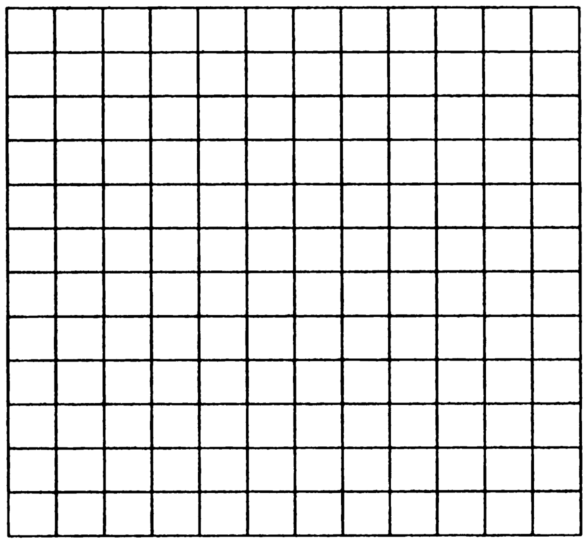
5. Calculate the mechanical advantage of each gear system. Which system is easiest to pedal?

6. What is the relationship between the MA value and the ease in pedaling?

7. Calculate the speed advantage of each gear system. What is the relationship between the SA value and the relative speed of the rear wheel?

8. Graph speed advantage vs. mechanical advantage.

- Label the y axis Speed advantage and the x axis Mechanical advantage.
- Plot SA values on the y axis and MA values on the x axis.



- From looking at your graph above, what is the relationship between mechanical and speed advantage?

9. Which gear combination would you use for climbing hills? Why?

10. Which gear combination would you use for racing on a level track? Explain your answer.

Appendix A – XV

Lab: Turtle Race

You are going to build a racecar. There's one catch, though: the last car across the finish line wins.

Here are the rules:

- Your car must be built entirely from LEGO parts.
- Your car cannot move backwards or sideways.
- The RCX must be part of your car.

Here are some hints:

- A successful car will probably include gearing down .
- The worm gear can be very useful.
- In this situation, friction is your friend.

Good luck!

Challenge Questions:

1. How long does it take your car to go twenty centimeters?

2. Make a sketch of the gear train of your snail car.

3. Does your car have other features to slow it down? If so, describe them.

Notes: Idea from www.ceeo.tufts.edu/curriculum/activities/3/snail_car.doc.
Refer to Constructopedia, pp 100-101 for construction help.

APPENDIX B

(SUPPLEMENTARY MATERIALS)

APPENDIX B-I

Velocity and Acceleration Practice

Directions: Work all problems in the space provided. Show all steps.

Step 1. FIND	What do you need to find?
Step 2. GIVE	What is given? List given information.
Step 3. SOLVE	-Choose the correct formula to use and write it down. -Rearrange the formula by getting "x" alone on the left side of the Equation. -Solve for x.

average velocity equation $v_{avg} = d/t$

1. Rearrange the average velocity equation to solve for d alone.

2. Rearrange the average velocity equation to solve for t alone.

3. If a cheetah can maintain a constant speed of 25 m/s, it covers 25 m for every second. How many meters will it go in 10 seconds?

4. On a car trip, you travel 240 km in 4 hours. What was your average speed, in km/hr?

5. Charlie can run an average of 8 km/hr. How long will it take for Charlie to run to the store 4.6 km away?

Acceleration equation: $a = (v_f - v_i)/t$

6. Calculate the acceleration of a car that can travel from 0 km/hr to 96 km/hr in 10 seconds.

a = ________________ (km/hr)/s

7. An apple falls out of a tree and accelerates at a rate of 9.8 m/s^2. Its total time in free fall is 2.0 seconds. How fast is it going (v_f) when it hits Isaac in the head?

V_f = __________________ m/s

8. A car decelerates from 100 km/s to 20 km/s. To rate of deceleration is -2.0 km/s^2. Calculate how long it takes for the driven to decelerate.

t= ________________________ s

APPENDIX B-II

Quiz: Distance, Velocity and Acceleration

I. Multiple Choice: Identify the letter of the choice that best completes the statement or answers the question.

__ 1. A mail truck takes 20 seconds to move between mailboxes that are 10 m apart. What is the average speed of the mail truck?
a. 200 m/s b) 5 m/s c) 2 m/s d) 0.5 m/s e) 0.2 m/s

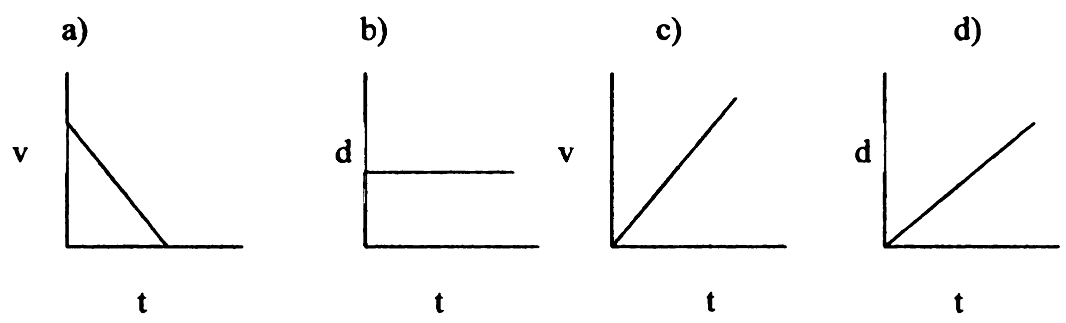
__ 2. If you want to calculate the acceleration of a car, you should ___ the change in velocity of the car by the time interval.
a) add b) decrease c) divide d) increase e) multiply

__3. Susan drops a ball, and 2 seconds later the ball has a speed of 20 m/s. What is the ball's acceleration?
a) 40 m/s^2 b) 20 m/s^2 c) 10 m/s^2 d) 5 m/s^2 e) 0 m/s^2

II. Short Answer: Answer in the space provided.

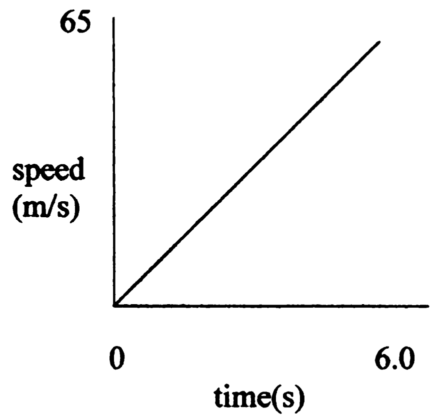
4. Two bicycle riders have the same speed. Do they have the same velocity? Explain your answer.

Use the graphs below to answer questions 5-7.
5. Which of the graphs shown below represents a car standing still?
6. Which of the graphs shown below represents a car moving at a constant speed?
7. Which of the graphs shown below represents a car moving at an increasing speed?



III. Problem Solving: Work all problems in the space provided. Show all steps.

8. Use the graph below to find the car's average acceleration:



9. Sound travels at 330 m/s. You hear the sound of the bat hitting a home run 0.5 seconds after you see it. How far way from the batter are you?

10. Dave is traveling at 20 m/s in a car when the car hits a tree. Dave comes to a complete stop in 0.4 seconds. What was Dave's acceleration?

IV. Matching: Write the letter of the definition tht matches the term in the space provided.

__ 11. constant speed	a. speed that does not change.
__ 12. average speed	b. rate of change in velocity
__ 13. velocity	c. total distance traveled / time
__ 14. acceleration	d. rate of motion at a given point in time
__ 15. instantaneous speed	e. a measure of speed with direction

APPENDIX B-III

Train Mystery

Read the news article below and complete the activity that follows.

News Flash: Bad News Gang Attempts Holdup
(From Choo Choo News, Vol.1)

Members of the so called "Bad News" gang were spotted near a 45.0 meter cliff, high above the Payroll Express train track yesterday, and they appeared to be "up to something", said officials at the Center for Train Safety.

This is the third time in as many weeks that the "Bad News" gang has allegedly tried to stop and rob the Payroll Express. By releasing a boulder from atop the high cliff so that it lands right in front of the train at the precise moment the train is below the edge of the cliff, the gang expects to make off with a sizable amount of money.

"It's a mystery to me," says train safety Officer Delta V. Platter, "how these rascals know how many seconds to wait before they let the boulder go. They must be able to tell how far away the train is when they drop it!" Early this morning, witnesses reported spotting some members of the gang spray painting one of the train rails white. Although investigators have declined comment, the white rail appears to be situated exactly 100.0 meters "up track" from the cliff, a telltale sign that the gang is planning another robbery.

Engineer Ima Constant runs this part of the rail, and she supports keeping the train running. "It's mighty important to keep your speed constant on this here stretch o'track. So, I keep this engine movin' at a pace of 20.0 meters per second. No slower, no faster."

The train company has issued a statement that they will not be driven by the "cowardly acts" of the gang. The train will leave the station, bound for the cliff today at its regularly scheduled time.

1. Fill out the data table below. You will need to calculate the boulder height by using the gravitational acceleration constant, 9.8 m/s^2.

Time (seconds)	Height of boulder from rail (meters)	Distance of train from starting point (meters)
1		
2		
3		
4		
5		

Show your calculations here:

2. Compare the motion s of the train and the boulder by graphing the following for each on graph paper (that's a total of four graphs):

- Boulder height vs. time
- Boulder velocity vs. time
- Train distance vs. time
- Train velocity vs. time

3. Make a cartoon motion picture booklet using the story and data above. Animate the drama using the accurate rates of movement for each object. You should end up with three frames to your cartoon.

Appendix B-IV

Ch 4 Practice Problems

Formulas:

F= ma	(note also	a= F/m; m = F/a)
p= mv	(note also	v= p/m ; m = p/v)
$g = 9.8\ m/s^2$	(g is a for freely falling objects on Earth)	

Directions: Use the Find/Give Solve format for solving each problem below. Show all steps.

1. A .25 kg bottle rocket haas a speed of 10 m/s. What is its momentum?

Find:

Give:

Solve:

2. A 20 kg running back has a momentum of 250 kg m/s. What it his velocity? (Hint: Use a form of p=mv that solves for v)

Find:

Give:

Solve:

3. Find the weight of the bottle rocket in problem 1 above.

Find:

Give:

Solve:

Appendix B-V

Ch 4 Quiz

Directions: Write answers using complete sentences. Show all steps for problems.

1. F= ma is sometimes known as Newton's second law. Explain this law in a statement.

2. Calculate the acceleration of a 50 kg Physical Science student that is pushed across the classroom with a force of 325N.

3. Alisha, a professional parachutist, jumps out of a plane in the sky. Draw a picture showing Alisha falling fast and faster. Be sure to include a gravity force vector and an air resistance force vector.

4. Tell me three characteristics of projectile motion:

1)

2)

3)

Appendix B- VI

Ch 4 Test
Acceleration and Momentum

I. Multiple Choice: Choose the best answer and bubble letter on the scan form provided.

1. The upward force exerted on an object falling through air is
a. terminal velocity b. momentum c. air resistance d. weightlessness

2. the statement "to every action there is an equal and opposite reaction: is Newton's
a. first law b. second law c. third law

3. In the equation, p= m x v, p represents
a. momentum b. force c. inertia d. velocity

4. The relationship between force, mass and acceleration is explained by Newton's
a. first law b. second law c. third law

5. A feather will fall more slowly than a brick because of
a. gravity b. air resistance c. terminal velocity d. momentum

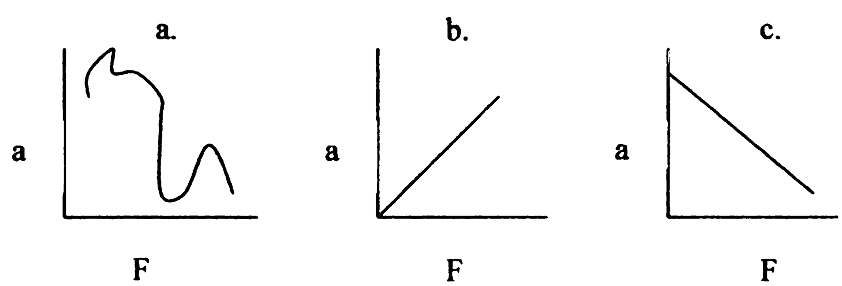
6. The path of a projectile is
a. straight b. always vertical c. always horizontal d. curved

7. If a 300 Newton action force is exerted to the right, the reaction force will be
a. 300N to the right b. 600N to the right c. 300N to the left d. 600N to the left

8. Acceleration due to gravity is
a. 98 m/s^2 b. 9.8 m/s^2 c. 9.8 m/s d. .98 m/s

9. A real car moving at 10 km/hr has more momentum than a toy car moving at the same speed because
a. its mass is greater b. its mass is less c. it moves faster d. of friction

10. As you increase the applied force on a cart, the cart's acceleration increases. Which of the following graphs show this relationship?



II. Problem Solving. Use FIND/GIVE/SOLVE steps to show your work.

11. What is the force of an object with a mass of 12 kg and an acceleration of 4 m/s^2?

12. What is the mass of an object that is accelerating at 15 m/s^2 when a force of 3000N is exerted?

13. Calculate the momentum of an object with a mass of 20 kg traveling at 25 m/s.

III. Short Answer: Answer using complete sentences.

14. How does a satellite stay in orbit around the earth?

15. You are ice skating at the rink with a friend. While standing still, you push on your friend in front of you. Your friend moves away from you. Describe which way you move. Be sure to use the term *momentum* in your answer.

APPENDIX B- VII

NOVA Rollercoaster Video Worksheet

Directions: Write answers in the spaces provided.

1. List the names of the amusement parks highlighted in this video:

a.
b.
c.
d.

2. Timeline Match: Draw lines to match the time on the left with the event on the right.

1800's	Coney Island
early 1900's	Disney opens
1920's	Depression
1932	Boom time for new rides
1955	Golden Age
End of the 20^{th} century	Ferris Wheel introduced

3. When you go on a typical steel roller ride like the Magnum at Cedar Point, you experience different forces on your body. Use these terms as you answer the following questions: acceleration, velocity, inertia, gravity, weight, net force

What does it feel like to go up the first steep hill?

What does it feel like immediately after you go over the first steep hill?

What force keeps you going forward on a rollercoaster?

What makes you feel weightless at the top of a loop?

What makes you feel heavy at the bottom of a loop?

4. Answer the following question in one paragraph: What are steel rollercoasters better than wooden rollercoasters?

APPENDIX B-VIII

A Lesson on Mechanical Advantage and Efficiency
(text reference: pp 182-200)

This lesson will clarify objectives to be covered in Activities 13 and 14.

The actual mechanical advantage is the number of times that a machine multiplies the effort force.

AMA= resistance force/ effort force
As an example, if it requires 2.5 N of effort force to move a 5N block up a ramp, the mechanical advantage is 2.

The ideal mechanical advantage is the mechanical advantage in the absence of friction.

IMA = [effort(input) distance]/ [resistance (output) distance]

For example, if the 5N block was pulled 90 cm up the incline and the incline is 20 cm high, then the IMA is 20cm / 90 cm or .22 .

What if you want to know how well a machine is running? One way is to determine its efficiency.

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} \times 100$$

Since Work = Force x distance, here's another way to find efficiency:

Efficiency = [AMA/ IMA] x 100

Both equations are saying the same thing, even though they don't look alike.

If you write the first one as

$$\text{Efficiency} = \frac{\text{Force}_{out} \times \text{distance}_{out}}{\text{Force}_{in} \times \text{distance}_{in}} \times 100$$

It is the same as

$$\text{Efficiency} = \text{AMA} \times \frac{\text{distance}_{out}}{\text{distance}_{in}} \times 100$$

Since $\frac{distance_{out}}{distance_{in}} = 1/IMA$

Efficiency = AMA x 1/IMA x 100 which brings us back to

Efficiency = [AMA/IMA] x 100

Questions for Understanding

1. What is the difference between the AMA and the IMA?

2. Even though there are two formulas above for efficiency, they are really measuring the same thing. Give *your* definition of efficiency.

3. Why is the actual mechanical advantage always lower than the ideal mechanical advantage?

4. Why can no machine ever be 100% efficient?

APPENDIX B- IX

Energy and Machines Test (Ch 5.1 and 7)

I. Multiple Choice: Bubble letter to the best answer on the scan form provided.

1. The ____ energy of an object increases with its height above the ground.
a) chemical b) kinetic c) mechanical d) potential

2. The kinetic energy of an object increases as its ____ increases.
a) specific heat b) velocity c) potential energy d)volume

3. The amount of work done when a force on one Newton acts through a distance of one meter is equal to a
a) Joule b) kilogram c) Celsius degree d) calorie

4. A slanted surface used to raise an object is _____.
a) an inclined plane b) a screw c) an effort ramp d) a wedge

5. A device that does work with only one movement and changes the size or direction of a force is _____.
a) a compound machine b) a simple machine c) an effort machine d) a wedge

6. A bar that is free to move about a fixed point (like a seesaw) is a
a) lever b) wedge c) fulcrum d) ramp

7. The rate at which work is done is ____.
a) efficiency b) effort time c) power d) force

8. The work output of a machine as compared to the work input is the ____ of the machine.
a)efficiency b) power c) effort d) resistance

9. The amount by which a machine multiplies an effort force is called the ____.
a) resistance force b) efficiency c) fulcrum d) mechanical advantage

10. A machine that can only change direction of a force has an MA of
a) 10 b) 5 c) 2 d) 1

11. An inclined plane wrapped around a cylindrical post is a ____.
a) wedge b) screw c) block and tackle d) lever

12. The unit of power is the ___.

a) Joule b) MA c) watt d) second

13. Three of the following simple machines are basically the same. Choose the one that DOES NOT belong with the group.
a) pulley b) wedge c) lever d) wheel and axle

14. A system of pulleys designed to reduce the effort force is called a
a) simple pulley b) fixed pulley c) movable pulley d) block and tackle

15. Which of the following CANNOT be done by a simple machine?
a) Change the direction of a force
b) Increase the amount of work done.
c) Decrease the time it takes to do the work.
d) Transfer energy from one location to another.

Study Fig 1 and 2 below. Then answer question 16-21 on your scan form.

Fig 1

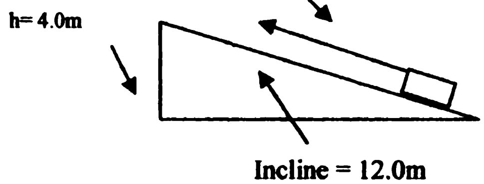
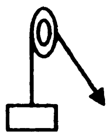


Fig 2



16. The MA of the inclined plane in Fig 1 is
a) 5 b)2 c) 3 d) 1

17. The weight of the block in Figs 1 and 2 is
a) 210 N b) 23 N c) 70N d) 140N

18. The amount of work required to move the block along the inclined plane is
a) 70J b) 280 J c) 700J d) 840J

19. If the weight of the block were doubled, the work required to move it up along the length of the inclined plane would be __.
a) half as much b) ¼ as much c) doubled d) quadrupled

20. If the efficiency of the fixed pulley were 100%, the forcerequired to loft the block off the ground would be ___.
a) 70N b) 210N c) 840N d) 280N

21. The fixed pulley ___.
a) doubles the force required to lift the block.
b) decreases the force required to lift the block.
c) makes the block easier to lift by changing the direction of the force need to lift it.
d) increases and changes the direction of the force.

II. Short Answer: Write answer using complete sentences.

1. Explain why you might shift into a lower gear to climb a hill on a bike. Your explanation should include a discussion of speed advantage and mechanical advantage.

2. Imagine you have a younger brother who weighs half as much as you do. Design a seesaw you could use together. Create a model of your seesaw design and label it to show the distances that you and your brother must sit from the fulcrum. Explain why you chose the fulcrum position that you did.

APPENDIX C

(Surveys and Data)

APPENDIX C-I

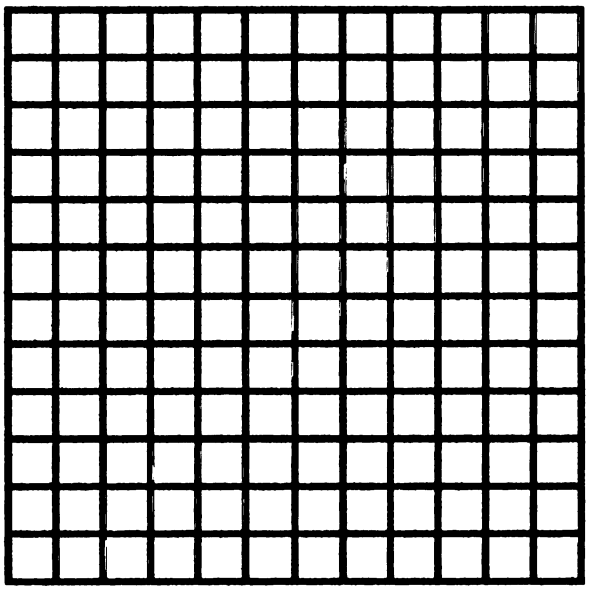
Motion and Energy Unit Pre-test

Directions: Answer questions in the space provided.

1. Write a paragraph about how fast you can walk using these terms correctly: distance, time, and velocity

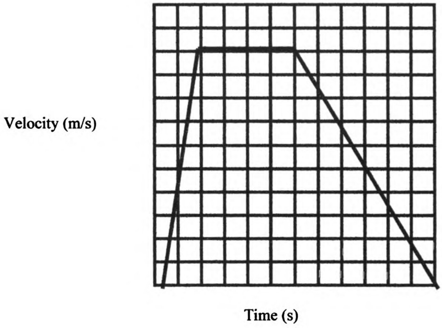
2. A physical science student walks 5m in 5 seconds. She then stopped for 2 seconds. Finally, she walks another 5m in 3 seconds. Graph this on the distance vs time graph below:

Distance (m)

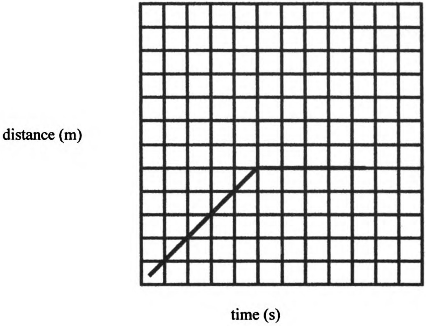


Time (s)

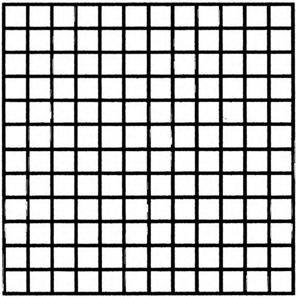
3. Use the terms velocity, acceleration, instantaneous velocity and time to describe the motion of a car from the following graph. In addition, show where the velocity is constant or changing.



4. This is a distance vs time graph for a car driving in front of the school.



Draw a velocity vs time graph based on the graph above. (Be sure to label the axes)



5. A 1 kilogram sack of feathers and a 1 kg lead weight are dropped simultaneously from a second floor window. Will they reach the ground below at the same time? Explain.

6. Explain the effect on a sky diver when he opens his parachute in terms of terminal velocity and air resistance.

7. It is the law to wear your seat belt if you are sitting in the front seats of a car. Explain the science behind this, being sure to cite Newton's First Law or Law of Inertia.

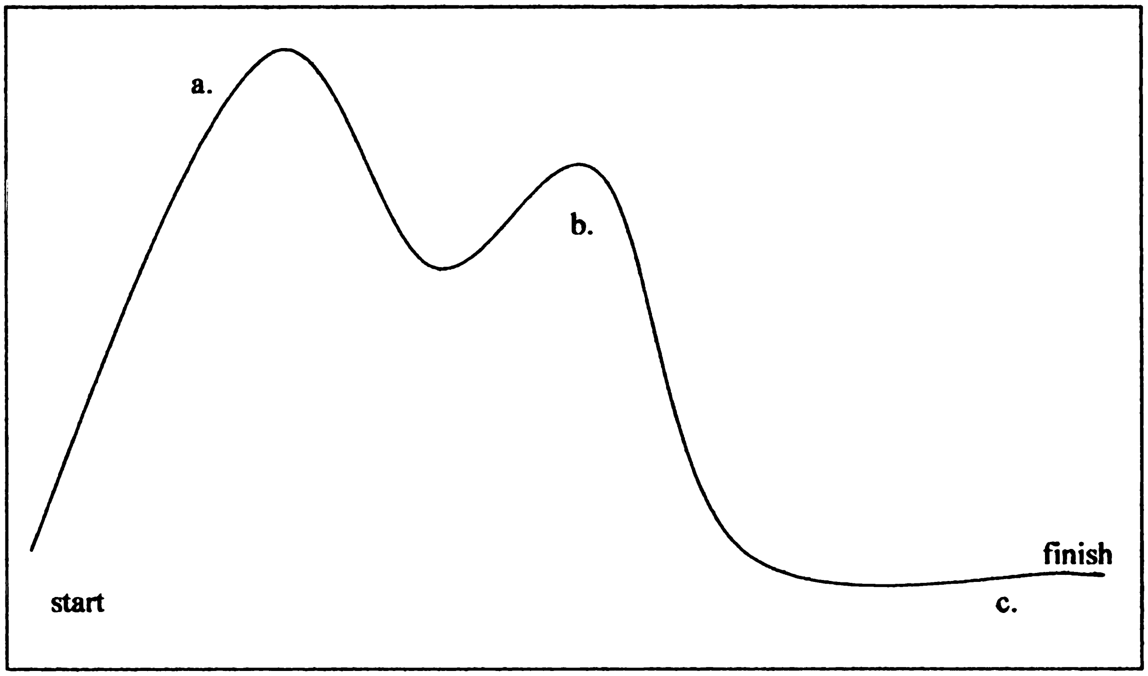
8. A 250g toy car and a 500g toy car are pushed across the table with the same force. Which car will have a greater acceleration? Explain your answer, using the following terms: inertia, force, mass, acceleration.

9. Explain what an action and reaction pair of forces is. Give an example.

10. What is the difference between potential and kinetic energy? How are they related?

11. How would the length of a pendulum swing affect its potential energy? How would it affect the kinetic energy of the pendulum?

12. Here's the outline of a rollercoaster. Label the points with the symbols for the following terms: Maximum potential energy (PE_{max}), Maximum kinetic energy (KE_{max}), and where kinetic and potential energy are equal (KE= PE).



13. From a science definition, what conditions must exist for work to be done?

14. Two machines do the same work. One machine takes twice as long to do the work. Which machine has twice the power?

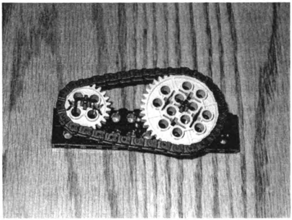
15. Based on problem 14, construct a definition of power using the terms work and time.

16. Why is the actual mechanical advantage always lower than the ideal mechanical advantage?

17. Why can no machine ever be 100% efficient?

18. a)In the gear combination below, turning the "pedal" clockwise would cause the rear gear to spin in what direction?

    b)Would this be an example of a gear chain with a high mechanical advantage or a high speed advantage?



19. List the six simple machines. Give examples of each type.

20. What is a complex machine? Give an everyday example.

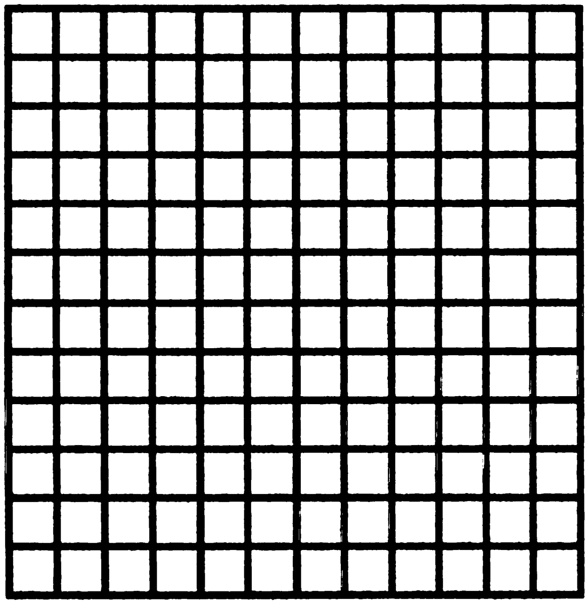
Problems:

21. A student can run the 100m dash in 12 seconds. Calculate how fast he is running in m/s.

22. The Top Thrill Dragster at CedarPoint is a coaster that goes from 0 to 120 mph in 4 seconds. What is the acceleration of the coaster in mph/s?

23. Graph the following data. The data represents the acceleration of an object as it is being pushed by a certain amount of force. Be sure to label the axes, plot the points and draw in the curve.

Force (N)	Acceleration (m/s^2)
10	1
15	1.5
20	2
25	2.5



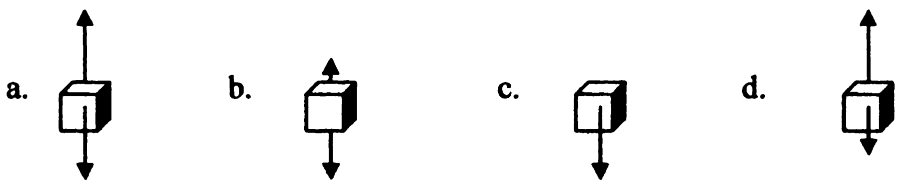
What does the slope of the graph represent?

APPENDIX C -II

Unit Post Test on Motion (multiple choice)

1. Which of the following is a complex machine?
   a) door knob b) bicycle c) crow bar d) screw

2. Which of the following diagrams shows that an object is still accelerating while falling?

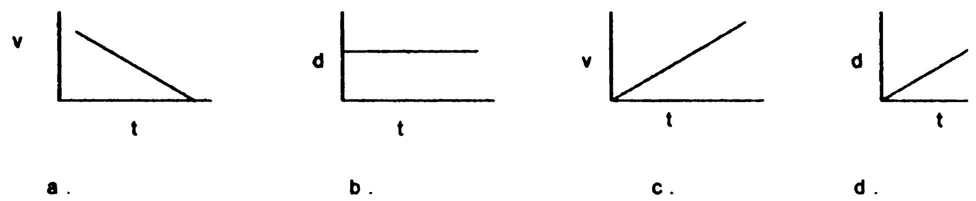


3. If you are standing on ice and you push your friend from behind,
   a. you both travel forward.
   b. You move closer to each other.
   c. You move backward and your friend moves forward.
   d. You move forward and you friend moves backward.

4. Where is the maximum amount of potential energy on a roller coaster?
   a) At the highest point b) At the lowest point c) in a loop

5. Where is the maximum amount of kinetic energy on a swing or a roller coaster?
   a) At the highest point b) at the lowest point c) at the mid point

6. A person in a head-on collision, who is not wearing a seat belt, continues to move forward at the original speed of the car because of
   a) friction b) inertia c) gravity d) weight



Use the Figure above to answer # 7-9:

7. Which of the following graphs represents a car standing still?
8. Which of the following graphs shows a slope with a positive acceleration?
9. Which of the following graphs shows a slope representing a car traveling at a constant speed?

10. If the force on a cart doubles, what happens to the cart's acceleration?
a) It quadruples b) It doubles. c) It halves. D) It quarters.

11. Two identical sheets of notebook paper (one is crumpled into a ball, one is not) are simultaneously dropped from a second story window under normal outdoor conditions. The crumpled ball of paper falls to the ground first because it has less ____ than the flat sheet of paper.
a) air resistance b) gravity c) inertia d) weight

12. John goes over the top of a hill at a speed of 4.0 m/s while on his bicycle. Four seconds later, his speed is 24 m/s. What is his acceleration?
a) 24 m/s^2 b) 20 m/s^2 c) 6 m/s^2 d) 5 m/s^2

13. Which swing length and position has the highest potential energy?
   a) long, pulled back to a height of 8 ft.
   b) short, pulled back to a height of 8 ft.
   c) long, not pulled back
   d) short, not pulled back

14. If I exert a force on a 20 lb box of books and I push it a distance of 10 meters I am doing
a) power b) work c) time D) inertia

15. The rate at which work is done is called
a) time b) energy c) power d) speed

16. Three of the following simple machines are basically the same. The one that does NOT belong with the group is
a) lever b) pulley c) wedge d) wheel and axle

17.When two or more simple machines work together, they are called a
a) compound machine b) an effort machine c) a screw d) a simple machine

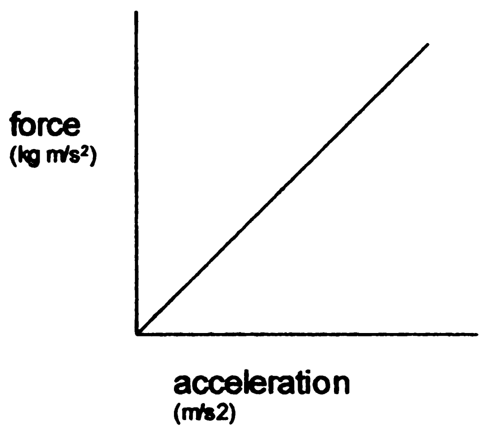
Use the following information to answer #21and 22:

A certain lever has an ideal mechanical advantage of 500. The actual mechanical advantage is only 100.

18. What is the efficiency of the machine?
a) 500% b) 100% c) 20% d) none of these

19. Why is the AMA lower than the IMA?
a) human error b) gravity c) levers are unreliable d) friction

20. Look at the graph below. The slope of the graph represents the
a) force b) mass c) acceleration d) velocity



21. The conversion of potential energy to kinetic energy and kinetic energy to potential energy demonstrated by a swing at the park is an example of

a) universal law of gravity
b) law of conservation of energy
c) law of action-reaction
d) law of inertia

22. Mrs. Erwin throws a softball 10 meters in 2 seconds. How fast is the ball traveling?
a) 5 m/s b) 2 m/s c) 10 m/s d) .2 m/s

23. When I drop a ball off a ten story building, the ball travels fast and faster as time goes by. This change of speed or direction over a period of time is called

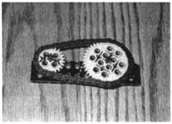
a) average speed b) acceleration c) inertia d) velocity

24. When a cannon ball is shot out of a cannon, the cannon "kicks" backwards. This is an example of

a) centripetal force b) frictional force c) terminal velocity d) action-reaction

25. Which of these correctly describes the motion of the gears shown below?

a. They turn in the same direction.
b. they turn in opposite directions.
c. They turn at the same rate.
d. The larger gear turns faster than the smaller gear.



26. Which combination would you select for high-speed bicycle travel on a level road?

a) large pedal gear, small wheel gear
b) small pedal gear, small wheel gear
c) large pedal gear, large wheel gear
d) small pedal gear, large wheel gear

27. Which combination would you select for bicycling up a steep hill?

a) large pedal gear, small wheel gear
b) small pedal gear, small wheel gear
c) large pedal gear, large wheel gear
d) small pedal gear, large wheel gear

APPENDIX C- III

Student Survey of Motion and Energy Activities

Student Name: ______________________________

Name of Activity: ______________________________

Directions: Answer questions in the space provided below.

1. **Summarize what you have learned from this activity.**

2. **Did the constructivist format of this activity help you form a deeper understanding of the concepts introduced?**

3. **Did the use of technology make this lab more interesting to you?**

APPENDIX C-IV

Student Survey of Motion and Energy Unit

Directions: Circle the appropriate number as your comment on each of the questions.
1= strongly agree 2= agree 3= indifferent 4= disagree 5= strongly disagree 6= not applicable

1. The lessons in this unit were easy to understand. 1 2 3 4 5
2. The length of time spent on each topic was appropriate. 1 2 3 4 5
3. I was able to understand concepts in this unit by arriving at them through experimentation. 1 2 3 4 5
4. Applying technology in the science classroom is fun. 1 2 3 4 5
5. Learning was easier with the use of technology. 1 2 3 4 5
6. Learning through doing the activities was more effective than learning by taking notes. 1 2 3 4 5
7. Graphing experimental data and analyzing the graphs helped me understand the relationships in motion. 1 2 3 4 5
8. The final project reinforced my understanding of the unit concepts. 1 2 3 4 5
9. The Legomindstorm activities inspired my interest in the fields of computer programming and engineering. 1 2 3 4 5
10. Use of the CBL/TI graphing calculators /sensors allowed me to reinforce math skills taught in math class. 1 2 3 4 5

Additional Comments:

APPENDIX C-V

Motion Unit Pre and Post Test Results, by concept ; N= 44

Topic	%correct-pre	%correct-post
speed	43	87
graph speed	57	91
calculate v	52	87
v/t graph	4	57
d/t to v/t graph	24	57
calculate a	57	50
free fall concept	41	76
freefall/air resistance	65	76
Newton's 1st Law	52	85
Newton's 2nd Law	63	57
graph a vs. F	61	37
Newton's 3rd law	50	83
PE vs Ke	17	50
Pendulum(I and E)	7	70
PE/KE and coaster	15	41
define work	4	89
work and power	63	57
define P using W and t	33	57
AMA vs IMA	9	59
Efficiency	9	50
gear directions	61	70
MA vs SA	41	61
simple machines	4	57
complex machine	26	61

APPENDIX C-VI

Motion Unit Pre and Post Test Results, by student; First Semester Group, N= 25

subject	%pretest	%posttest
1	43	88
2	39	75
3	43	68
4	13	80
5	22	72
6	65	98
7	22	62
8	9	57
9	13	52
10	22	37
11	35	58
12	30	88
13	39	78
14	57	78
15	35	82
16	35	80
17	52	100
18	26	49
19	30	65
20	35	69
21	35	69
22	43	71
23	22	77
24	22	71
25	74	100
Second	Group	N=19
1	30	85
2	26	56
3	43	63
4	35	70
5	17	56
6	26	78
7	48	74
8	43	85
9	65	85
10	26	44
11	35	41
12	26	67
13	35	56
14	30	67
15	57	85
16	39	81
17	35	81
18	17	37
19	57	89

APPENDIX C-VII

Paired Student's *t*-Test: Pre/Post Test Results by Student
(http://www.physics.csbsju.edu/cgi-bin/stats/Paired_t-test)

First Semester Group

The results of a paired t-test performed at 17:33 on 18-JUL-2004

t= 15.1
degrees of freedom = 24

The probability of this result, assuming the null hypothesis, is 0.000

Group A: Number of items= 25 **Group A is the post test**
37.0 49.0 52.0 57.0 58.0 62.0 65.0 68.0 69.0 69.0 71.0 71.0 72.0 75.0 77.0 78.0 78.0 80.0 80.0 82.0 88.0 88.0 98.0 100. 100.

Mean = 73.0
95% confidence interval for Mean: 66.53 thru 79.39
Standard Deviation = 15.6
Hi = 100. Low = 37.0
Median = 72.0
Average Absolute Deviation from Median = 11.8

Group B: Number of items= 25 **Group B is the pre test**
9.00 13.0 13.0 22.0 22.0 22.0 22.0 22.0 26.0 30.0 30.0 35.0 35.0 35.0 35.0 35.0 39.0 39.0 43.0 43.0 43.0 52.0 57.0 65.0 74.0

Mean = 34.4
95% confidence interval for Mean: 27.90 thru 40.98
Standard Deviation = 15.9
Hi = 74.0 Low = 9.00
Median = 35.0
Average Absolute Deviation from Median = 11.8

Group A-B: Number of items= 25
15.0 21.0 23.0 23.0 25.0 26.0 28.0 33.0 34.0 34.0 35.0 36.0 39.0 39.0 40.0 45.0 45.0 47.0 48.0 48.0 49.0 50.0 55.0 58.0 67.0

Mean = 38.5
95% confidence interval for Mean: 33.24 thru 43.80
Standard Deviation = 12.8
Hi = 67.0 Low = 15.0
Median = 39.0
Average Absolute Deviation from Median = 10.3

Paired Student's *t*-Test: Results, Second Semester Group

The results of a paired t-test performed at 17:41 on 18-JUL-2004

t= 10.9
degrees of freedom = 18

The probability of this result, assuming the null hypothesis, is 0.000

Group A: Number of items= 19 **Group A is the post test**
37.0 41.0 44.0 56.0 56.0 56.0 63.0 67.0 67.0 70.0 74.0 78.0 81.0 81.0 85.0 85.0 85.0 85.0 89.0

Mean = 68.4
95% confidence interval for Mean: 60.55 thru 76.29
Standard Deviation = 16.3
Hi = 89.0 Low = 37.0
Median = 70.0
Average Absolute Deviation from Median = 13.5

Group B: Number of items= 19 **Group B is the pre test**
17.0 17.0 26.0 26.0 26.0 26.0 30.0 30.0 35.0 35.0 35.0 35.0 39.0 43.0 43.0 48.0 57.0 57.0 65.0

Mean = 36.3
95% confidence interval for Mean: 29.92 thru 42.71
Standard Deviation = 13.3
Hi = 65.0 Low = 17.0
Median = 35.0
Average Absolute Deviation from Median = 9.95

Group A-B: Number of items= 19
6.00 18.0 20.0 20.0 20.0 21.0 26.0 28.0 30.0 32.0 35.0 37.0 39.0 41.0 42.0 42.0 46.0 52.0 55.0

Mean = 32.1
95% confidence interval for Mean: 25.91 thru 38.30
Standard Deviation = 12.8
Hi = 55.0 Low = 6.00
Median = 32.0
Average Absolute Deviation from Median = 10.5

APPENDIX C-VIII

Motion Unit Student Survey Results; N = 44

Question #	% students strongly agree	% students agree	% students indifferent	% students disagree	% students strongly disagree
1	0.0	43.2	50.0	6.8	0.0
2	0.0	61.4	13.6	25.0	0.0
3	4.5	56.8	25.0	13.6	0.0
4	43.2	31.8	18.2	6.8	0.0
5	47.7	31.8	13.6	6.8	0.0
6	43.2	25.0	18.2	9.1	4.5
7	4.5	43.2	31.8	15.9	4.5
8	13.6	31.8	36.4	15.9	2.3
9	18.2	45.5	18.2	18.2	0.0
10	4.5	50.0	25.0	13.6	6.8

APPENDIX C- IX

Fall2003/Spring 2004 motion unit physical science: evaluation summary (student responses to questions 1-3)

- Activity #1: 1) students learned teamwork and how to calculate speed, velocity and acceleration. A few students noted that the project prompted them to use the following skills: patience, precision, following directions, and logic (for programming the robots). 2) Students felt that learning to program the robots allowed them to understand the concepts step by step. Students commented that "you can actually see the motion", making it easier to understand velocity. 3) It was novel for them to use robots to study motion. They took ownership of their team robots. Students found the lesson challenging because they had to construct their own robots, programs, debug their programs. They felt that the technology was more interesting that learning the concepts straight from the book. They became motivated by the end objective: to get their robot to come closest to stopping precisely at the 1 meter mark. Three students mentioned that the technology did not necessarily make a difference for them.
- Activity #2: Interpreting Position vs Time Graphs: 1) Students learned how to transfer a graph into a program and have the robot complete the path. Students then realized the connection between the graph and the path.2) Students related that they can really see what the connection is when they "put the graph into action". One student commented that she has difficulty learning concepts this way and prefers learning from the textbook. 3) Students mention that they enjoy learning it this way as compared to the book. Two students mentioned that it did not really make a positive difference for them.
- Activity 3: Distance vs Time, Velocity vs. Time Graphs: 1) Students compared d vs t graphs with v vs. t graphs. 2) At this point, students began understand the Lego robot programming and troubleshooting better. Students prefer learning this way.3) Except for two students, most students found that the technology made the activity engaging. One student replied, ".. because its cool how everything works by programs you designed".
- Activity 4: Acceleration: 1) Students learned that the steeper the incline, the greater the acceleration. In the first method, Students conceptually placed the cart in between two photogates to find the acceleration from one photogate to the next. In method two, students used a motion detector that was able to detect a change in velocity over time. In the first case, students calculated the acceleration by formula. In the second case, students analyzed v vs t graphs generated by the calculator. 2) A majority of the students understood the lesson because of the combination of visually seeing the cart accelerate and technically collecting and analyzing data. 3) Students expressed a high interest in using the technology to enable them to do the lab. They cited ease of use, ease of understanding, time efficiency, interest and accurate data as reasons for liking technology in this lab. Student comments included, "this equipment is really cool", "I actually got good results", and "this lab was easy and I get it".

- Activity 5: Vector Addition: 1) Students learned that the sum of the vectors is the shortest distance between the start and end points. 2) Students enjoyed coming up with the steps to reach the target. However, (and this is my gut feeling, I don't think this lab is getting to the point. I think students need to make 2 moves to get to the target and compare that to 1 move. Upon graphing the vectors, they should see the trig relationship. 3) I am sensing that the lack of clarity or true goal in this lab caused some frustration for the students. A typical student comment was, "The bot would not do what I wanted it to do".
(I thought this lab was poorly constructed, so I did not use it second semester)
- Activity 6: Free Fall Activity: 1) Students experienced how objects with different air resistance accelerate by using a motion detector. 2) Students can see the construction of the concept by visually seeing the downward force of gravity and the upward air resistance. Terminal velocity became a tangible concept. 3) There was a problem getting the motion detectors to work. A typical first semester student comment was, "I spent most of my time getting the CBL to work". This became a good problem to have, as students had to troubleshoot the equipment in order to get good results. Second semester students had a better experience with it. Two students felt they needed more reinforcement on the concepts.
- Activity 8: Newton's 2nd Law: 1) Students discovered the relationship between force, mass and acceleration. 2) Student comments: " you can understand it because you can actually see it"; " " the graphs actually help you see the acceleration of the cart" . Four students commented that the lab was difficult for them. 3)The equipment worked efficiently(students rotated into the labs with ease), and the students found the graphs helpful in their understanding of the concepts. One student said hands on made it "brains on" for her. One student was excited about learning by using equipment (accelerometers and force sensors) that he never knew existed. One student felt that the calculator based technology made the calculations and the F=ma relationships easier for him to understand.
- Activity 9: Newton's 3rd Law: 1) For every force exerted, there was an equal and opposing force. Tension on a string was equal to the weight of the object it supported. A single pulley simply changes the direction of the force. 2) Students liked the many tests that were done to reinforce their understanding of how action forces exert an equal and opposite force. Students could see the forces on the spring scale and see the opposing forces immediately. 3) Technology did not really play a role in this lab.
- Swinging Energy Activity: see text p132-133: 1) Students determine if a pendulum will continue swinging if a crossarm is placed in its path. Students examine the concept of energy transfer, kinetic vs potential energy. 2) The scenario set (the pendulum as a swing at the park) created a visual for the students to follow through on. 3) Technology was not really a factor in this lab.
* I substituted this activity with a Rollercoaster project for the second semester group.
  1) Students designed a rollercoaster. Students analyzed the motion and energy of a marble as it travels down the model rollercoaster.

2) Students discovered the energy conversions for themselves as they used trial and error to build the requirements into their marble coaster.
3) Students were highly engaged in the project as it promoted creativity and an end product that would show off their product. Some students said, "Our group's (rollercoaster) was the best". The calculations were challenging for the students. "Building the coaster was fun, but I didn't like all the math involved", mentioned a student.

- Activity 11: Work and Power 1) Students have a pull back car go up an inclined ramp. Students calculate the power of their car. 2) Students found the experiment to be understandable, although there were some challenges in getting the students to show the calculations, with units. I will provide a data table for this one. On part B, I will only do the minimum power. 3) Students really found this interesting and enjoyed the cars. A student comment was, "Can we do more labs like this one?"
- Activity 12: Lesson on Mechanical Advantage and Efficiency.(Prep for activity 13, 14)
- Activity 13: Which machine is more efficient? Part I: Efficiency on an Incline(class); Part II: efficiency of a pulley(demo); Part III: efficiency of a lever(demo) . 2) Students found all 3 activities to be very visual and helpful in constructing the concepts and understanding. Calculations weren't always clear. 3) Technology was minimal. Student comments included, "I could see all the machines and use them to problem solve" and "it was awesome how you can use the lego parts in this lab, especially the gear chains".
- Activity 14: Gears 1) Students compared MA vs SA on a model of a bicycle gear combination. 2) Students definitely got into using Lego bricks and gears to create the various gear combinations. Students could feel the difference in the "pedaling". The calculations were easy, using the # of teeth for gear size. Should have the students graph SA vs 1/MA to get a linear slope. 3) the Legos were an excellent tool!
- Activity 14b: Turtle Race (second group only) 1) To build a Lego car for a "slowest wins" race. 2) Students spent two days building the car. I have never seen them work so hard. I would definitely say that they were using everything that they had studied from the motion unit in order to complete this unit project. 3) Students really got into the construction of the gear train. In addition, students that enjoyed programming explored ways of slowing the car down by changing the motor power and using less motors. Students were also able to explain the gearing, frictional forces, and energy transfers that allowed their cars to move at a certain speed. Student comments included, "Can we do this for one more day?" and "It was hard, but I really got a lot out of it".

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