Sara Audrey Kwitek

PHY 690

Exploring Motion and Forces with Seventh Grade Students

A paper completed in partial fulfillment of PHY690: Masters' Project in Physics Education
for the Department of Physics, State University of New York (SUNY)--Buffalo State College.
Supervised by Dr. Dan MacIsaac, November, 2004.

ABSTRACT

This study focuses on the seventh grade students' knowledge have about motion and force. A total of 110 students completed an instrument before and after instruction involving the different concepts involved with the unit. The "Exploring Motion and Forces" revised edition of the instrument is included.

INTRODUCTION

The purpose of this study was twofold: to measure students' knowledge before and after a unit on motion and forces, and to determine the effectiveness of teaching. To truly determine a student's initial knowledge, thoughts, and ideas upon a particular subject teachers and researchers must give out a pretest and compare it to posttest results. This paper was built around an instument, *Exploring Motion and Force*, developed for the study to find out what grade seven students know about motion and forces.

Research has shown that there are benefits of having students complete instrument pre and post instruction. There is a test that is widely used by physics teachers called the *Force Concept Inventory (FCI)* by Hallouin and Hestenes. The Force Concept Inventory is similar to this in that it measures student's initial thoughts and ideas, and effectiveness of instruction. "The *Force Concept Inventory* (FCI) is a unique kind of 'test' designed to assess student understanding of the *most basic* concepts in Newtonian physics. It can be used for several different purposes, but the most important one is to evaluate the effectiveness of instruction."[3] However, it differs in that *Exploring Motion and Forces* is designed for middle school physical science, not high school physics.

The *Exploring Motion and Forces* pretest and posttest was given in a middle class suburban school district located in Western New York where there are approximately one thousand and forty students. The school consists of two grade levels, seventh and eighth. In seventh grade, students complete one whole year of physical science. In eighth grade every student completes one full year of life science.

During instruction, students that participated in this study experienced a non-traditional learning style setting to maximize the effectiveness of learning, because research has shown that traditional teaching styles do not alter the original idea students may have on a particular topic as much as a cooperative learning based classroom setting. "*Traditional* (lecture-demonstration) physics instruction induces only a small change in the beliefs," [2] whereas "*Cooperative Inquiry* has become increasingly popular in recent efforts to reform K – 12 science education, and it is strongly advocated by educational researchers."[7] Therefore, participating students were engaged in many hands-on activities, demonstrations, cooperative inquiry, and modeling lessons. Each of these methods of teaching have all been proven most effective in a classroom setting, according to research, in addition, helpful with altering students' beliefs.

METHOD

Participants

There are four seventh grade physical science teams at the participating school. The original sample consisted of one team, which consists of five classes containing approximately twenty-three students in each class. The unit was covered in approximately three weeks. The students attended nine periods in a day, about forty-two minutes long, five times a week. They attended one physical science lesson a day. Each student completed a pretest before the unit was

taught, and posttest after three weeks of daily instruction, testing their ability to recall information on motion and forces.

A total of one hundred and ten seventh grade students participated in this study. Ten assessments were eliminated from this study because they were not present for both pretest and posttest. The students ranged in age from about eleven to thirteen. Some of the students that participated in the study were advanced in mathematics, and were completing an algebra course. Table 1 shows the characteristics of the participants.

Table 1
Characteristics of the participants

	Period				
Characteristic	Second	Third	Forth	Sixth	Ninth
Gender					
Male	8	9	11	11	9
Female	15	11	10	12	14
Ethnicity					
White	21	20	21	22	23
African-American	2	0	0	1	0

Task and Procedure

The students were tested in a quiet classroom setting for approximately forty-two minutes. Each student completed a pretest and posttest surveying their knowledge on motion and forces. The objectives of this particular unit provided by the student's textbook are listed in Table 2, which is found on the following page. [1]

Table 2

Chapter Sections	Objectives
Motion & Speed	1. **Define** *speed* as a rate. 2. **Perform** calculations involving speed, time, and distance. 3. **Interpret** distance-time graphs.
Velocity & Acceleration	1. **Compare** and **Contrast** speed, velocity, and acceleration. 2. **Calculate** acceleration.
Connecting Motion with Forces	1. **Recognize** different examples of forces. 2. **Give** examples of the effects of inertia. 3. **State** Newton's first law of motion.
Gravity- A Familiar Force	1. **Give** examples of the effects of gravity. 2. **Relate** gravitational force to mass and distance 3. **Distinguish** between mass and weight

Exploring Motion and Forces was designed by combining questions found in the following three books: Glencoe: Physical Science, [1] which is also the classroom textbook, Conceptual Physics, [4] and Intermediate-Level: Science Big 8 Review Book. [6] The test consisted of a total of thirty-six questions each worth one point. Questions one through twelve, fourteen, and sixteen through twenty-five consisted of multiple choice questions. Questions thirteen, fifteen, and twenty-six through thirty-six required student constructed responses.

Teaching Experience

DATA

The results of the student's pretest and posttest scores are displayed in Table 3 and Table 4 on the following page. Each table displays the question along with the number of student responses to each answer. A program, provided and designed by Proffessor Zawicki, was used to determine the difficulty of each question and discrimination, which is also provided in the data tables. The discrimination column tells how well the better scoring students did compared to the low scoring students. A discrimination close to 1.0 means there was a big gap between how many of the better scoring students did on that question compared to the low scoring students

and it probably is a good question to use. A negative discrimination means that many of the low scoring students did better than the high scoring students and it probably was not a good question.

Table 3

Pretest Results

Question #	Credit (pts.)	Difficulty	Discrimination	Response # 1	Response #2	Response #3	Response # 4	Response #5
1	1	0.78	0.34	2	18	86	4	0
2	1	0.04	-0.16	4	36	0	7	61
3	1	0.7	0.36	77	10	16	7	0
4	1	0.18	0.02	66	20	12	3	0
5	1	0.82	0.3	6	90	8	6	0
6	1	0.04	-0.05	6	4	62	37	0
7	1	0.49	-0.07	54	5	36	14	0
8	1	0.16	-0.06	33	18	41	18	0
9	1	0.46	0.04	51	29	24	5	0
10	1	0.46	0.08	2	47	51	8	0
11	1	0.92	0.06	2	5	2	101	0
12	1	0.73	0.07	80	29	0	1	0
13	1	0.42	0.25	46	0	0	0	0
14	1	0.71	0.22	78	32	0	0	0
15	1	0.32	0.3	35	0	0	0	0
16	1	0.53	0.14	58	6	32	12	0
17	1	0.27	0.08	8	42	30	28	0
18	1	0.27	0.21	12	16	30	48	0
19	1	0.3	0.22	24	33	15	36	0
20	1	0.24	0.01	77	5	1	26	0
21	1	0.52	0.23	57	17	15	19	0
22	1	0.54	0.38	4	59	28	18	0
23	1	0.72	0.41	23	4	79	3	0
24	1	0.52	0.37	15	57	12	25	0
25	1	0.26	0.34	24	6	49	29	0
26	1	0.55	0.51	60	0	0	0	0
27	1	0.19	0.15	21	0	0	0	0
28	1	0.49	0.44	54	0	0	0	0
29	1	0.15	0.28	17	0	0	0	0
30	1	0.06	0.19	7	0	0	0	0
31	1	0.55	0.32	60	0	0	0	0
32	1	0.66	0.39	73	0	0	0	0
33	1	0.01	0.13	1	0	0	0	0
34	1	0.14	0.38	15	0	0	0	0
35	1	0	0	0	0	0	0	0
36	1	0.4	0.26	44	0	0	0	0

Table 4

Posttest Results

Question #	Credit (pts.)	Difficulty	Discrimination	Response # 1	Response #2	Response #3	Response # 4	Response #5
1	1	0.95	0.93	2	3	105	0	0
2	1	0.86	0.87	0	4	4	6	95
3	1	0.85	0.84	94	8	6	2	0
4	1	0.25	0.4	73	27	10	0	0
5	1	0.81	0.86	13	89	7	1	0
6	1	0.44	0.59	5	48	36	21	0
7	1	0.52	0.54	57	17	26	9	0
8	1	0.32	0.49	27	35	41	6	0
9	1	0.77	0.8	85	14	8	3	0
10	1	0.53	0.62	2	45	58	5	0
11	1	0.95	0.91	3	2	1	104	0
12	1	0.99	0.96	109	1	0	0	0
13	1	0	-0.96	60	0	0	0	0
14	1	0.81	0.81	89	21	0	0	0
15	1	0	-0.96	78	0	0	0	0
16	1	0.73	0.74	80	7	15	8	0
17	1	0.88	0.88	7	3	97	3	0
18	1	0.36	0.49	12	23	40	35	0
19	1	0.62	0.71	8	68	26	8	0
20	1	0.46	0.56	55	1	3	51	0
21	1	0.79	0.83	87	15	2	6	0
22	1	0.68	0.76	8	75	5	22	0
23	1	0.7	0.75	16	8	77	9	0
24	1	0.76	0.78	16	84	6	4	0
25	1	0.46	0.61	43	2	13	51	0
26	1	0.88	0.87	97	0	0	0	0
27	1	0.92	0.9	101	0	0	0	0
28	1	0.88	0.88	97	0	0	0	0
29	1	0.39	0.52	43	0	0	0	0
30	1	0.21	0.43	23	0	0	0	0
31	1	0.86	0.87	95	0	0	0	0
32	1	0.83	0.83	91	0	0	0	0
33	1	0.05	0.21	6	0	0	0	0
34	1	0.35	0.55	39	0	0	0	0
35	1	0.11	0.29	12	0	0	0	0
36	1	0.53	0.61	58	0	0	0	0

ANALYSIS OF DATA

To make a perfect assessment on the first trial is merely impossible, as I have discovered during the process of this study. However, this is what teaching is all about, taking what we know and utilizing it to make it better for the future. This next part of the paper analyzes each question and evaluates whether or not it was considered for the revised edition *Exploring Motion and Forces* test.

Question # 1- "A car travels 120 km in 3 hours. What is its speed?" [6]

I would like to begin the analysis by focusing on the first question. This question was written to check the student's knowledge on speed. According to the *New York State Intermediate Level Core Curriculum, Grades 5-8*, Performance Indicator 5.1b states," The motion of an object can be described by its position, direction of motion, and speed."[5] In other words, can the students determine the speed of a moving object based on the information of distance and time?

According to the data, approximately 78% of the students answered with the correct answer of 40 km/hr in the pretest. There was a low discrimination of 0.34 between the high-level students and the low-level students. After the posttest was given out 95% of the students answered the question correctly with a high discrimination close to 1.0. What this shows is that the students, who previously did not know the correct answer to question one, must have learned how to calculate speed problems throughout the unit.

Question # 2- "What is the acceleration of a car that travels from 0 km/hr to 88 km/hr in 10 seconds? [6] *"*

According to the core curriculum guide, acceleration is a concept related to motion that the students should be familiar with. The results of the pretest shows about 55% of the students were able to answer this question correctly as 8.8 km/hr/s, with a discrimination of 0.47 between the high and low students. After the posttest was given out, 86% of the students answered this question correctly with an even higher discrimination of 0.87.

Initially, many students chose their response as 88 km/hr/sec. This tells me that before this unit there were many students that could not easily distinguish between speed and acceleration. This could possibly be due to the fact that they experience speed and acceleration about everyday when they observe the speedometer change from 0 km/hr to 88 km/hr during a car ride. When they are traveling at 88 km/hr they are thinking that is how much they accelerated to, not taking into consideration that yes, they are traveling at that speed, but that was the speed the car reached over the time frame of 10 seconds.

Question # 3- "What information is required in order to measure speed?" [6]

This question kind of goes hand in hand with the first question. It is used to check student's knowledge on the two factors that determine speed. Approximately 70 % of the students answered this question correctly with a discrimination of 0.36. Many of the students know that distance and time are required to measure the speed of a moving object. As in question two, the post-assessment results were very similar. This time 85% of the students answered correctly and there was a discrimination of 0.84, which tells there is a high difference between how many advanced students answered correctly compared to lower knowledge

students. Students could not guess on the answer, they had to be familiar with the concept of speed.

Question # 4- "Which of the following graphs best shows acceleration?" [6]

The choices in this question show four different graphs. The students had to determine which graph was the best choice for showing acceleration. The results from this question are pretty interesting considering the discrimination was 0.02 and 18% of the students answered this question correctly on the pretest. According to the data, many students are unfamiliar with acceleration graphs. The students do not understand that acceleration is the slope of a distance-time graph. The most popular choice for this question is the first graph, which shows a straight line on a distance-time graph.

Even after instruction on this topic, students still chose the first graph. In fact, more students changed their minds and picked the first graph, rather than the second graph, which is the correct response. 25% of the students picked the correct choice with 0.4 discrimination. This is a valid question to keep on the revised edition of the test based on the fact that one of the objectives for this unit is to interpret graphs. However, I would spend more instructional time distinguishing the differences between velocity and acceleration graphs with the students.

Question # 5- "When a car is accelerating, the distance traveled per unit of time ___." [6]

Approximately, 82% of the students answered this question correctly by saying that the distance traveled per unit of time increases, with 0.3 discrimination. In the post-assessment scores, only 81% answered correctly, but the discrimination increased drastically to 0.86. This tells that there were many students that guessed on the pretest.

The other interesting aspect about this question is how there seemed to be an agreement with the other most chosen choice. Initially, six students chose response 'a,' which says that the distance per unit of time decreases and in the posttest that number increased to thirteen students. It is possible students were not listen carefully and make good observations in class during an exercise on how both speeding up and slowing down are called acceleration. Because of this problem, the question should be reworded to state, "When a car is positively accelerating, the distance that the car travels during equal intervals of time ___." This should help the students to distinguish between positive and negative acceleration.

Question # 6 - " You wear seatbelts in a car because of ___."[6]

One of the concepts that we introduce in physical science is Newton's first law. Another name for this law is the Law of inertia. This next question was designed to test the students on their ability to recall vocabulary they learned in this unit. This question gives the students a real life example of a scientific concept that they could relate to. The pretest results show that this concept is really a concept neither the high or low students would get, because the discrimination is –0.05. Only 4% of the students answered this question correctly, which shows many of the student probably guessed on the answer.

The posttest score shows that 44% of the students answered this correctly and that the discrimination is now 0.59. These results are showing which students know the definition of inertia. However, it is not a valid enough question, because there is still less than half of the class that understands what inertia is. The students that did not choose inertia as their choice picked choice 'c,' which is force, mass, and acceleration, or choice 'd', which is action/reaction. To steer students away from these choices, next year I would have the students complete an

activity that shows Newton's first law more clearly and discuss the reason behind the importance of a seatbelt.

Question # 7 - "A ball bounces because of ___." [6]

As mentioned earlier on, there would be a few questions that should be eliminated from the revised edition of the test, because they are invalid questions. This is one of those questions. The reason the question is invalid is because there are actually two correct multiple choice responses to this question. Gravity was intended to be the correct answer, however, action/reaction would be correct if it were chosen. 49% of the students answered this question correctly, but the problem contains a discrimination of –0.07. Fifty-four students chose gravity as their answer. Fourteen students chose action/reaction. It is possible that the reason the discrimination is low is because the higher students chose action/reaction because that is indeed a correct choice even though they have not learned about it yet. The post-assessment scores show 52% of the students answered correctly and the discrimination increased to 0.54, which is not much more than before.

Question # 8 - "A force is needed to move a stationary car because of ___." [6]

Question eight is similar to question six in that is tries to recall the same concept of inertia. In addition, the pretest results are very similar. 16% of the students answered this question correctly and there was a discrimination of -0.06 before instruction occurred, the posttest results only showed 32% of the students were able to answer this question correctly. The discrimination was 0.49, which is about half of the surveyed team. This is a topic that definitely needs to be addressed longer with the students.

Many students chose the choice that includes force, mass, and acceleration. According to the student's experience, they know the reason that it is hard to move a car is because it is massive. However, they are ignoring the fact that inertia also, deals with the concept of mass. After all, inertia is the tendency of an object to resist a change in motion based on its mass. I would change this question so that choice 'c' was not included.

Question # 9 – "As the distance between two masses increases, the gravitational pull ___." [6]

Question nine is used to measure whether or not students understand the relationship between mass and gravitational pull. In fact, the *New York State Intermediate Science Level Curriculum* [5] guide requires the students to know this concept. Major understanding 5.2a states, "Every object exerts gravitational force on every other object. Gravitational force depends on how much mass the objects have and how far apart they are." [5] About 46% of the students chose the correct answer that the gravitational pull decreases. However, that was probably based purely on guessing because the discrimination was 0.04.

After instruction was given, the number of students that chose the correct answer rose to 77%. To change the students thinking about the gravitational pull versus the distance between masses, we held a classroom discussion comparing it to two magnets. By doing this, the students could relate gravitational pull with something they all are already familiar with. This is a much better percentage of students that know the correct answer. Students did not guess on this question and this is shown with a 0.80 discrimination. A lower discrimination, smaller than 0.80, would mean just as many advanced students did not know the correct answer as the lower knowledge students.

Question # 10- "Which diagram best displays the motion of a baseball being thrown to a catcher." [6]

The purpose of this question was to test the student's understanding of the concept of projectile motion. However, the way that the question was worded was very misleading to many students. There were four choices to choose from, each showing a path the baseball may follow. The correct choice for this question is choice 'c,' which shows a parabolic curve in the path. Since the question specifically states the ball is being thrown to a catcher, it triggers the student's experience where a baseball being thrown to a catcher is moving at 90 mph. To them the ball is going to move in an almost straight path, with a tiny amount of a parabolic curve. The students that do not really know much about baseball are going to pick the correct choice, because that is how they see the ball thrown when they play casual catch. I would change this question so that it says, " Which diagram best displays the motion of a softball being thrown in a game of casual catch?"

As far as the results are concerned, they follow what was just previously mentioned. Initially, 46% of the students chose the correct answer, which increased to 53% after instruction. The discrimination factor also increased from 0.08 to 0.62. The higher students knew what the correct answer should be and everyone else chose their intuition from naïve interpretation of their observed experience. Ideally, we observe more closely and reinterpret experiences via discourse.

Question # 11 – "In which diagram would the person need the least effort to move the box up the ramp? Explain." [6]

Because it was too easy, this question was eliminated. The question gives four diagrams of a person pushing a box up a ramp and asks which box is the easiest to push up the ramp. Both

in the pretest and the posttest the majority of the students picked choice ‘d’ because the box was on wheels.

Question # 12- “When an astronaut goes to the moon his ___ changes.” [6]

Question twelve is not a very valid question either. The discrimination was 0.07 and the difficulty was 73%. In the Intermediate-Level: Science Big 8 Review Book, there is a section that focuses on weight as a force. It states, “Weight is due to the pull of gravity on a given mass. The larger the mass, the greater its response to the pull of gravity. Since the mass of the Moon, and therefore its gravitational pull, is less than the mass of the Earth, you eight less on the moon. The greater the mass of a person on Earth, the more the person will weigh. However, it must be understood that when an astronaut goes to the Moon, only his weight changes, his mass stayed the same.” [6]

From the information given from the review book, I created question twelve. The two choices that students could have chosen from are weight and mass. Since the students had a fifty-fifty chance, he or she could have guessed the correct answer. Therefore, the results are completely irrelevant.

Question # 13- “A small car and a large truck have a head on collision. The small car is knocked backwards as the tuck, although slowed, continues to move forward. Why did the small car move backwards?”

This question, too, was one that I had created, which could be considered irrelevant and was eliminated from the revised edition of the test. The discrimination was 0.25 and the difficulty was 42 %. At this point in the curriculum, students have not learned about Newton’s

third law and Law of Conservation of Momentum. This material was presented during units that occurred later.

Question # 14 – "According to the graph below, which of the two cars moved faster? Explain." [6]

Question fourteen shows one graph with two straight lines with different slopes, each representing the speed of two separate cars. The y-axis is labeled distance and the x-axis is labeled time. The students had to determine which of the two cars was moving faster. If the students chose car A then they received one point. 71% of the students chose car A in the pre-assessment test. In the post-assessment test 81% of the students chose car A. This is good because more students were able to read the graph and see that the steeper the slope on a distance-time graph the faster the object is moving.

Question # 15- "Examine the graph below. Explain what happened at section 2 of the graph."[6]

This question also involves the interpretation of a graph. These type of questions are valid tools for measuring whether or not students can visually see what is happening with an object by looking at a graph. The graph is set up the same way as in question fourteen, however the line demonstrates an object moving at a constant velocity, resting, and then moving once again with a constant velocity. If the students stated that the car was at rest, stopped, or the distance did not change, they received one point. According to the results, 32% of the students answered this question correctly. The discrimination between the high and low students is 0.30. After instruction occurred, seventy-eight students were able to say the car was resting. Thirty-two students still wrote the incorrect response.

Since this is a valid question on determining whether or not students truly understand what is occurring in a distance versus time graph, this question will remain on the posttest. However, there will be one change and that is to make it into a multiple-choice question.

Question # 16 - "The best way to describe the rate of motion of an object that changes speed several times is to calculate the object's ___." [1]

During the Pretest, 53% of the students answered this question correctly. However, there is a discrimination of 0.14, which means that many of the students probably guessed what the answer should be. The post-assessment shows an increase of 73% of the students answered it correctly with a discrimination of 0.74.

Question # 17 - "Which of the following is a force ___?" [1]

The next question is unique because all students have experienced friction in their everyday. However, not many students view friction as a force. In fact, more students chose acceleration as a force over friction. The initial results showed that 27% of the students chose friction and the posttest results showed 88%. Therefore, the activities and demonstrations during instruction proved to be helpful with this concept.

Question # 18 - "The unit for ___ is m/s^2." [1]

One of the most important concepts students need to understand is the importance of units next to a numerical value. Units are very important in that it helps a person know the purpose and value of the number in front of it and what it measures. Initially, many students chose the units in this question to represent velocity. 27% of the students answered this question

correctly. There was a very low discrimination between the high students and low students. Unfortunately, there was not a significant difference in the posttest results. Only 36 % of the students chose acceleration as their answer, but there was 0.49 discrimination, which means that the higher performing students know it is acceleration and the lower performing students still believe that m/s^2 is the units for velocity.

Question # 19 – "Which of the following is not used in calculating acceleration?" [1]

During the past three weeks of instruction, the students were responsible for learning how to solve acceleration problems. Question nineteen asks if the students could recall the information that is necessary in order to solve an acceleration problem. Before instruction 30% answered correctly, but there was a discrimination of 0.22, which means that really no one had any idea and they all guessed. After the unit was completed, only 62% were able to recall the information necessary to solve an acceleration problem. The higher students were able to recall this information, which is shown in the discrimination as 0.71.

This question will remain on the posttest as a multiple-choice question. To enable more students to receive credit for answering this question correctly, I would spend more time having students experiment with discourse upon the difference between velocity and acceleration.

Question # 20 - "A body accelerates if it _____." [1]

From everyday experience students are familiar with the vocabulary word accelerate. To them it involves an object speeding up. Question twenty is used to measure if the students know what acceleration in science terminology means. According to the data, seventy-seven students

chose speeds up. After instruction, fifty-one students chose choice 'd', which includes all of the answers. Fifty-five students were still determined to choose speeds up as their answer.

If this question were altered a little, so that it says, "A body accelerates positively if it ___", another question were added that states, "A body accelerates negatively if it ____", this would distinguish which students know that acceleration is associated with direction. I think that if this question were split into two questions and included the words positive and negative, that the students would not be mislead to just choose speeding up as their answer.

Question # 21 - "The gravitational force between two objects depends on their ____." [1]

Even if the students did not know the answer to this question, they could have recalled the correct answer from a previous question. Approximately, 52% of the students answered correctly in the pretest and 79% of the students answered it correctly in the posttest. In the posttest, the next popular choice was velocity.

Question # 22 -, "___ acts only between surfaces that are in contact." [1]

What is unique about question twenty-two is how 54% of the students initially know that friction acts between two surfaces, but did not correlate their response with friction acting as a force. The other popular response to this question was gravity. Many of the students might have chosen gravity because gravity acts between two objects and they might have just misinterpreted it. During instruction, I would spend more time undertaking activities and discourse comparing friction versus gravity, emphasizing friction as a force that acts between two objects that are in contact.

Question # 23 - " An object's weight is directly related to its ____." [1]

Question twenty-three should be eliminated from the revised version of the test. About 79% of the students chose mass as the correct answer in the pretest. Only 77% of the students chose mass in the post-assessment, which means there were a few students that were guessing. The next popular choice is volume. These students that are choosing volume are correlating size with how heavy something is. They believe that the larger the volume or size of the object is, the more an object weighs.

Question # 24 - "An object of large mass has ___ than an object of small mass." [1]

Question twenty-four goes back to the idea of inertia, again. Approximately, 52% of the students answered the question correctly with more inertia. From the results of earlier inertia questions, which students did not know the correct answer, it appears that most students guessed on the answer because the discrimination factor was a low 0.37. In the posttest, 76% of the students chose more inertia as their answer and there was a higher discrimination of 0.78. This question was kept in the revised edition of the test.

Question # 25 - "A constant velocity means acceleration is ____." [1]

This is a great question to measure whether or not the students know the relationship between velocity and acceleration. Consistent with earlier results, the pretest shows that students are unfamiliar with the concept of acceleration. Twenty-six percent of students answered this question correctly. Forty-nine students chose increasing as their answer. In the post-assessment students converted their responses to positive instead and 46% answered correctly. Forty-six percent is still not a high number of students that answered this question correctly, which means

that instruction may need to be altered in some way. Many students were still choosing what they already were familiar with from previous knowledge. Therefore, in order for the students to change their experience I would have them describe a situation to me, using the terms velocity and acceleration. This way the students would be able to use their own words and hear themselves use the terms correctly.

The next series of questions are all constructed response questions. Unfortunately, these were not answered as expected, so the grading system is a little different then what it originally was going to be used. In the revised edition of the test, all constructed response questions will be eliminated or altered to be multiple choice.

Question # 26 – "What is the average speed of a cheetah that sprints 100m in 4 seconds? How about if it sprints 50m in 2s?" [4]

Question twenty-six was used to check if the student's answers could support what he or she chose in the first question under the multiple-choice section. If the students did not have the correct units, they were not penalized. The pre-assessment results show 55% of the students answered this question correctly. The discrimination between high and low students is 0.51. After instruction took place, 88% of the students knew how to find the answer to question twenty-six. The discrimination was 0.87, which means that only the really low students did not know how to answer this question. This question is altered to be a multiple-choice question. The new question states, "If one cheetah sprints at a speed of 100m in 4s and another cheetah sprints 50m in 2s, the first cheetah has the _____ speed as the second cheetah?" The students will have to choose from greater, the same, equal, or less. Altering question twenty-six this way will still measure whether or not students understand how to calculate speed.

The students experienced a lot of instruction time on finding the speed of objects. A major activity that contributed to their knowledge of finding the speed of moving objects is when the students worked in groups to develop their own method on how to find out if the cars driving in front of the school were going the speed limit or not.

Question # 27 -"The speedometer of a car moving to the east reads 100 km/hr. It passes another car that moves to the west at 100 km/hr. Do both cars have the same speed? Do they have the same velocity? Explain." [4]

In physical science, we do not use the terminology of scalar quantities and vector quantities. However, the students are responsible for knowing that difference between speed and velocity is related to direction. Question twenty-seven was used to measure whether or not students understood this difference.

According to the data, the students initially did not think there was any difference between speed, and velocity. Most students responded by telling they were the same and direction did not matter. Initially, 19% of the students answered this question correctly.

Again, this question was altered in the revised edition of the test. The new question states, "The speedometer of a car moving to the east reads 100 km/hr. It passes another car that moves to the west at 100 km/hr. The cars have _____." The students will be able to choose from the following: same speed and velocity, different speed and velocity, neither speed nor velocity.

Question # 28 – A particular car can go from rest to 90 km/hr in 10 seconds. What is its acceleration? [4]

This question was designed to test student's knowledge on acceleration. Can the students figure out if an object acceleration if given the speed and time? Initially, fifty-four students answered this question correctly with a discrimination of 0.44. They were given credit if they had the correct numerical value. Units were neglected. After instruction, ninety-seven students answered this question correctly with a discrimination of 0.88.

This question will be altered as a multiple-choice question. The question will stay the same, but it will have multiple choice responses to go along with it. The students will be able to choose from the following: 90 km/hr, 90km/hr/s, 9 km/hr, or 9 km/hr/s.

Question # 29 – In 2.5 s a car increases its speed from 60 km/hr to 65 km/hr while a bicycle goes from rest to 5 km/hr. Which undergoes the greater acceleration? Explain. What is the acceleration of each vehicle? [4]

This question is similar to question twenty-six in that it checks to see if students are consistent with how they figure out how to solve for acceleration with multiple-choice question two. If the students did not have the correct units, they were not penalized. The pre-assessment results show seventeen students answered this question correctly. The discrimination between high and low students is 0.28. After instruction took place, only forty-three students knew how to find the answer to question twenty-nine. The discrimination was 0.52 with a difficulty level of 0.39, which clearly shows many students had a difficult time understanding this concept.

This question was altered into two multiple-choice questions in the revised edition. The new question states, "In 2.5 s a car increases it speed from 60 km/hr to 65 km/hr while a bicycle

goes from rest to 5 km/hr. The cars acceleration is _____ than the bike." The students will be able to choose from three of the following choices: less than, more than, or equal to.

The second part of this question would state, "What is the acceleration of the car and bike?" The students will have to choose from the following: 65 km/hr and 5 km/hr, 5 km/hr/s and 5 km/hr/s, 65 km/hr/s and 5 km/hr/s, or 5km/hr and 5km/hr. Altering question twenty-nine this way will still measure whether or not students understand the concept of acceleration and it will make it fair to assign credit of one point each.

Question # 30 – The greater the slope of the incline, the greater the acceleration of the ball. What is the acceleration if the incline is vertical? [4]

The problem with this question is that the answer requires the students to respond by telling gravity is the reason the ball accelerates on a vertical incline. Because this question was too vague many students did not understand what the question was asking for. This is proven by the data results which show seven students answered the question right on the pretest and only twenty-three students answered it correctly on the posttest. Because students are not mind readers, the problem with this question can easily be solved if it were changed into a multiple-choice question. The question on the revised edition states, "As you can see in the diagrams below, each ball starts to accelerate more and more as the incline of the plane gets higher and higher. Why does the ball accelerate if it is dropped down a wall?" The students will be able to choose from the following: friction, gravity, air resistance, or inertia.

Question # 31 – Will the coin drop into the glass when a force accelerates the card? Explain. [1]

In the revised edition of the test, this question is eliminated. Students received a point if they stated whether or not the penny would fall into the glass. This question was too easy and it did not measure what it was intended to.

Question # 32 – Can you tell an object has moved if you do not see it move? Explain. [1]

This is an important concept that the students should understand. In order to tell how far and how long something has moved, a reference point must be included and a unit scale of some sort. Students received the point if they said, "Yes, you can tell the car moved." Very few students included anything about using a reference point, which is what this question is looking for. Seventy-three students answered it correctly in the pretest. Ninety-one students answered this question correctly in the posttest. Even though this question was revised, the concept behind the question remained the same. The revised question states, "If your eyes are closed, you can tell an object has moved according to its_____." The students will be able to choose from the following: inertia, force, reference point, or gravity.

Question # 33 – Explain how it is possible for an automobile traveling at a constant speed to be accelerating. [1]

Initially, only one student answered question thirty-three correctly. In the post-test, six students answered this question correctly. Many responses included that this was not possible. If this question was altered so that it was a multiple "In order for an automobile to accelerate while moving at a constant speed, the automobile must be _____." The students have the following choices to choose from: moving up hill, moving down hill, moving in a circle, or cannot happen. By altering the question into a multiple-choice question, the students are not left

with their initial reaction of it cannot happen. Given different situations in the multiple-choice responses, students are more likely to think about the question before they answer.

Question # 34 – Friction and gravity are both forces. Describe two differences between them. [1]

Since question twenty-two from the original test asks which force acts only between two surfaces and question thirty asks why a ball accelerates down an incline plane, question thirty four was eliminated from the revised edition of the test.

Question # 35 – What is the difference between mass and weight? [1]

Question thirty-five was too vague of a question to ask the students. This shows in the data results when not one student received credit in the pretest and only twelve students received credit on the posttest. Since question twelve was eliminated from the revised edition test, this question could not be eliminated. There needed to be at least one question that measures whether or not students know the difference between mass and weight.

In order to convert this question into a multiple-choice question, it had to be broken down into two questions. The first question states, "If a monkey travels to the moon, his *mass* will _____?" The second question states, "If an elephant travels to the moon, her *weight* will _____?" In both questions, the students will chose from the following choices: increase, decrease, stays the same, or neither. By asking these questions and providing multiple choice responses, you are eliminating extraneous responses and getting right to the point. This question will give a better discrimination between the high and low learners.

Question # 36 – A car sits motionless on a hill. What forces are acting on the car? Are the forces balanced or unbalanced? Explain.[1]

This concept of Newton's third law is not covered in this particular unit. This unit only covers Newton's first law. Therefore, this question was eliminated from the revised edition of the test.

CONCLUSION

In conclusion**,** many middle school students initially did not have much knowledge about motion and forces. After instruction, the students gained knowledge through the use of a non-traditional learning style setting.

Based on the gain results, I would recommend that teachers use the revised edition of this test (appendix) for testing student knowledge on motion and forces. If you decide to make your own revisions to the test, I would encourage it! The process of making a measurable test was difficult. The revised edition of the test is perfect for teachers that want to get a quick measure of students' knowledge on motion and forces. However, if you are more interested in how students can explain what they are thinking, I would suggest using written response questions, or interviewing students one-on-one. Interviewing students is definitely more time consuming, but you will be more pleased with responses.

Tests were evaluated based on the Hake gain approach. The Hake gain approach involves subtracting the pretest from the posttest scores and then dividing it by the pretest score subtracted from the maximum score. Gain greater than 0.30 is good. Gain greater than 0.45 is very good. Table 5 shows the results from the assessments.

Table 5

Test Results

Student/ Gender	Pre-Test	Post-Test	Hake Gain	Student/ Gender	Pre-Test	Post-Test	Hake Gain
1 M	13	23	0.43	56 M	7	21	0.48
2 M	16	22	0.30	57 M	19	29	0.58
3 M	22	26	0.28	58 F	16	25	0.45
4 M	16	23	0.35	59 M	14	24	0.45
5 F	13	22	0.39	60 M	22	30	0.57
6 M	10	23	0.50	61 F	15	22	0.33
7 F	19	26	0.41	62 M	18	25	0.38
8 F	14	19	0.22	63 M	15	26	0.52
9 F	18	23	0.27	64 M	13	14	0.04
10 M	15	22	0.33	65 F	12	16	0.16
11 F	18	18	0.00	66 M	13	19	0.26
12 F	15	24	0.42	67 F	9	20	0.40
13 F	20	25	0.31	68 F	19	22	0.17
14 M	10	18	0.30	69 M	19	26	0.41
15 F	12	21	0.37	70 M	14	23	0.40
16 F	11	22	0.44	71 M	13	20	0.30
17 F	11	24	0.52	72 F	12	22	0.41
18 M	12	26	0.58	73 M	10	18	0.30
19 F	19	28	0.52	74 M	11	19	0.32
20 F	15	24	0.42	75 F	18	24	0.33
21 F	18	27	0.50	76 M	14	29	0.22
22 F	13	17	0.17	77 M	16	26	0.50
23 F	17	21	0.21	78 F	14	24	0.45
24 F	20	23	0.18	79 F	14	15	0.04
25 M	12	23	0.45	80 F	17	23	0.31
26 M	16	25	0.45	81 M	15	26	0.52
27 F	13	23	0.43	82 F	10	20	0.38
28 F	19	22	0.17	83 F	18	20	0.11
29 M	21	29	0.53	84 M	17	23	0.31
30 M	15	24	0.42	85 F	12	24	0.50
31 M	19	30	0.64	86 F	17	29	0.63
32 M	18	29	0.61	87 M	20	26	0.37
33 M	14	21	0.31	88 F	18	25	0.38
34 F	19	27	0.47	89 F	12	19	0.29
35 F	18	19	0.05	90 F	17	23	0.31
36 F	13	20	0.30	91 F	15	30	0.71
37 F	12	25	0.54	92 F	15	21	0.28
38 F	23	24	0.07	93 F	16	25	0.45
39 M	15	23	0.38	94 M	6	22	0.53
40 F	18	30	0.66	95 M	21	31	0.66
41 F	13	21	0.34	96 M	16	24	0.40
42 F	14	16	0.09	97 F	15	23	0.38
43 M	18	27	0.50	98 F	13	29	0.26
44 F	17	23	0.31	99 M	14	18	0.18
45 F	12	23	0.45	100 F	16	21	0.25
46 M	17	25	0.42	101 F	22	21	-0.07
47 M	14	16	0.09	102 M	21	21	0.00
48 M	19	27	0.47	103 M	13	27	0.60
49 F	19	28	0.52	104 F	17	25	0.42
50 F	13	19	0.26	105 M	17	19	0.10
51 F	18	23	0.27	106 M	8	26	0.64
52 F	12	20	0.33	107 F	12	9	-0.12
53 M	21	28	0.46	108 F	10	14	0.15
54 F	11	24	0.52	109 F	15	22	0.33

55	F	12	23	0.45	110	M	12	15	0.08

APPENDIX

The following pages consist of the original and revised motion and forces test. They may be reproduced or altered for classroom use.

Original Test

NAME_____ PERIOD_____

EXPLORING MOTION AND FORCES

1. A car travels at 120 km in 3 hours. What is its speed?

   a. 123 km/hr b. 60 km/hr c. 40 km/hr d. 20 km/hr

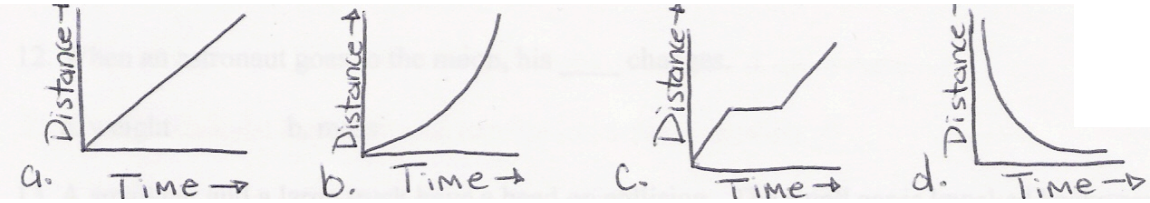
2. What is the acceleration of a car that travels from 0 km/hr to 88 km/hr in 10 seconds?

   a. 98 km/hr/sec b. 88 km/hr /sec d. 9.8 km/hr/sec e. 8.8 km/hr/sec

3. What information is required in order to measure speed?

   a. time & distance b. velocity & time c. distance & velocity d. momentum & time

4. Which of the following graphs best shows acceleration?



5. When a car is accelerating, the distance traveled per unit of time

   a. decreases b. increases c. remains the same d. doubles

6. You wear seatbelts in a car because of

   a. gravity b. inertia c. force, mass, and acceleration d. action/reaction

7. A ball bounces because of

   a. gravity b. inertia c. force, mass, and acceleration d. action/reaction

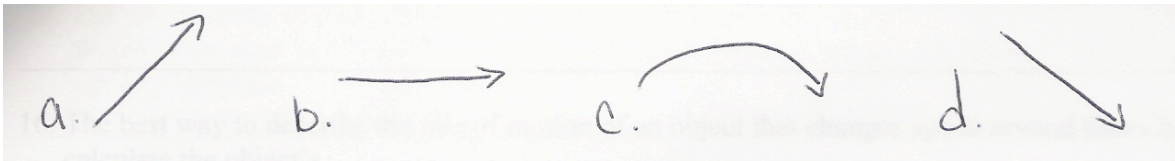
8. A force is needed to move a stationary car because of

   a. gravity b. inertia c. force, mass, and acceleration d. action/reaction

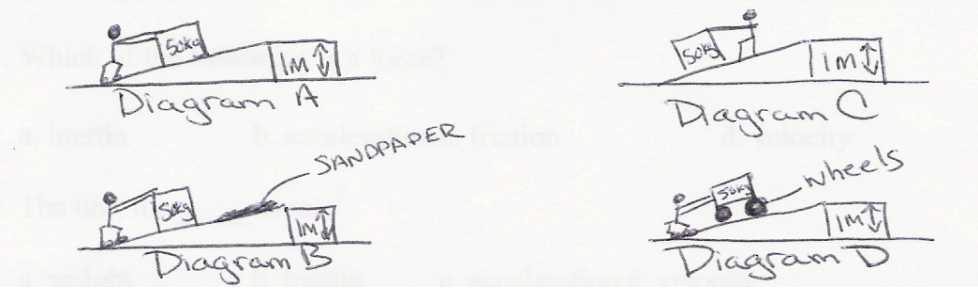
9. As the distance between two masses increases, the gravitational pull

a. decreases b. increases c. remains the same d. doubles

10. Which diagram best displays the motion of a baseball being thrown to a catcher?



11. Carefully examine the diagrams A-D, which show a person moving a box up a ramp.



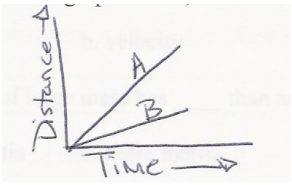
a. In which diagram would the person need the least effort to move the box up the ramp? Explain.

12. When an astronaut goes to the moon, his ____ changes.

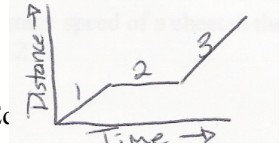
a. weight b. mass

13. A small car and a large truck have a head on collision. The small car is knocked backwards as the truck, although slowed, continues to move forward. Why did the small car move backwards?

14. According to the graph below, which of the two cars moved faster? Explain.



15. Examine the graph below. Explain what happened at section 2 of the graph.



16. The best way to describe the rate of motion of an object that changes speed several times is to calculate the object's _____.

    a. average speed b. instantaneous speed c. constant speed d. variable speed

17. Which of the following is a force?

    a. inertia b. acceleration c. friction d. velocity

18. The unit for _____ is m/s^2.

    a. weight b. inertia c. acceleration d. velocity

19. Which of the following is not used in calculating acceleration?

    a. initial velocity b. average speed c. time interval d. final velocity

20. A body accelerates if it _____.

    a. speeds up b. slows down c. changes direction d. all of these

21. The gravitational force between two objects depends on their ____.

    a. masses b. velocities c. shapes d. volumes

22. _____ acts only between surfaces that are in contact.

    a. Inertia b. Friction c. Gravity d. A net force

23. An object's weight is directly related to its _____.

    a. volume b. velocity c. mass d. shape

24. An object of large mass has ____ than an object of small mass.

    a. less inertia b. more inertia c. less weight d. greater acceleration

25. A constant velocity means acceleration is _____.

    a. positive b. negative c. increasing d. zero

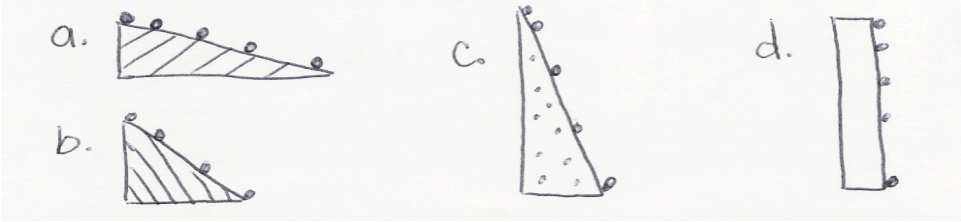
26. What is the average speed of a cheetah that sprints 100 m in 4 seconds? How about if it sprints 50 m in 2 s?

27. The speedometer of a car moving to the east reads 100 km/hr. It passes another car that moves to the west at 100 km/hr. Do both cars have the same speed? Do the have the same velocity? Explain.

28. A particular car can go from rest to 90 km/hr in 10 seconds. What is its acceleration?

29. In 2.5 s a car increases its speed from 60 km/hr to 65 km/hr while a bicycle goes from rest to 5 km/hr. Which undergoes the greater acceleration? Explain. What is the acceleration of each vehicle?

30. The greater the slope of the incline, the greater the acceleration of the ball. What is the acceleration if the incline is vertical?



31. Will the coin drop into the glass when a force accelerates the card? Explain.

32. Can you tell an object has moved if you do not see it move? Explain.

33. Explain how it is possible for an automobile traveling at a constant speed to be accelerating.

34. Friction and gravity are both forces. Describe two differences between them.

35. What is the difference between mass and weight?

36. A car sits motionless on a hill. What forces are acting on the car? Are the forces balanced or unbalanced? Explain.

Revised Edition

NAME_____ PERIOD_____

EXPLORING MOTION AND FORCES

1. A car travels at 120 km in 3 hours. What is its speed?

   a. 123 km/hr b. 60 km/hr c. 40 km/hr d. 20 km/hr

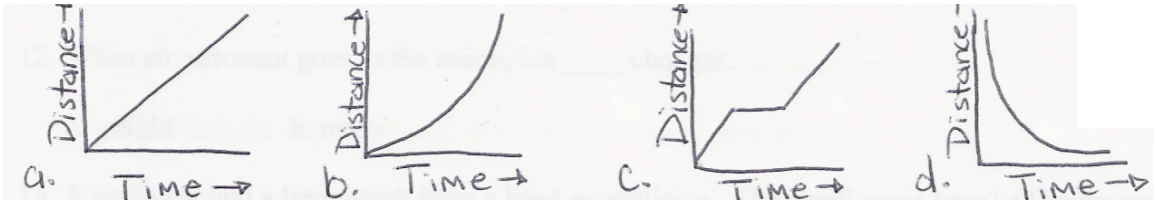
2. What is the acceleration of a car that travels from 0 km/hr to 88 km/hr in 10 seconds?

   a. 98 km/hr/sec b. 88 km/hr /sec d. 9.8 km/hr/sec d. 8.8 km/hr/sec

3. What information is required in order to measure speed?

   a. time & distance b. velocity & time c. distance & velocity d. momentum & time

4. Which of the following graphs best shows acceleration?



5. When a car is accelerating, the distance traveled per unit of time

   a. decreases b. increases c. remains the same d. doubles

6. You wear seatbelts in a car because of

   a. gravity b. inertia c. force, mass, and acceleration d. action/reaction

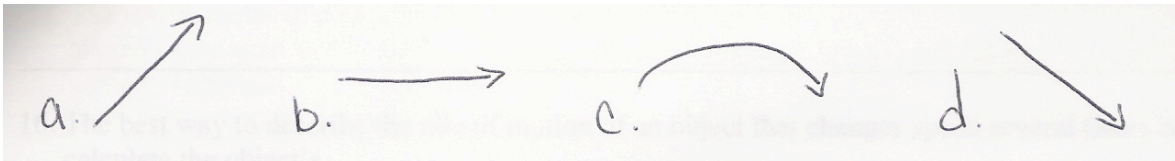
7. A force is needed to move a stationary car because of

   a. gravity b. inertia c. force, mass, and acceleration d. action/reaction

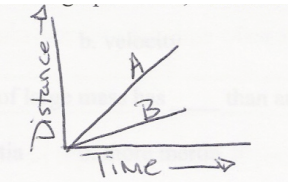
8. As the distance between two masses increases, the gravitational pull

a. decreases b. increases c. remains the same d. doubles

9. Which diagram best displays the motion of a softball being thrown in a game of casual catch?

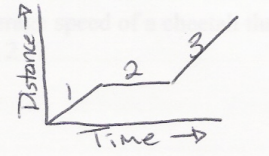


10. According to the graph below, which of the two cars moved faster?



a. Car A b. Car B

11. Examine the graph below. The speed of the car _____at section 2 of the graph?



a. increased b. decreased c. stopped d. remained the same

12. The best way to describe the rate of motion of an object that changes speed several times is to calculate the object's _____.

a. average speed b. instantaneous speed c. constant speed d. variable speed

13. Which of the following is a force?

a. inertia b. acceleration c. friction d. velocity

14. The unit for _____ is m/s^2.

a. weight b. inertia c. acceleration d. velocity

15. Which of the following is not used in calculating acceleration?

a. initial velocity b. average speed c. time interval d. final velocity

16. A body accelerates positively if it ___.

a. speeds up b. slows down c. changes direction d. all of these

17. A body accelerates negatively if it ____.

a. speeds up b. slows down c. changes direction d. all of these

18. The gravitational force between two objects depends on their ____.

a. masses b. velocities c. shapes d. volumes

19. _____ acts only between surfaces that are in contact.

a. inertia b. friction c. gravity d. a net force

20. An object of large mass has ____ than an object of small mass.

a. less inertia b. more inertia c. less weight d. greater acceleration

21. A constant velocity means acceleration is _____.

a. positive b. negative c. increasing d. zero

22. If one cheetah sprints at a speed of 100m in 4s and another cheetah sprints 50m in 2s, the first cheetah has

the _____ speed as the second cheetah?

a. greater b. the same c. equal d. less.

23. The speedometer of a car moving to the east reads 100 km/hr. It passes another car that moves to the west

at 100 km/hr. The cars have _____.

a. same speed and velocity b. different speed and velocity c. neither speed or velocity.

24. A particular car can go from rest to 90 km/hr in 10 seconds. What is its acceleration?

a. 90 km/hr b. 90km/hr/s c. 9 km/hr d. 9 km/hr/s.

25. In 2.5 s a car increases it speed from 60 km/hr to 65 km/hr while a bicycle goes from rest to 5 km/hr. The

cars acceleration is _____ than the bike.

a. less than b. more than c. equal to.

26. According to the situation in question twenty-six, what is the acceleration of the car and bike?

a. 65 km/hr and 5 km/hr b. 5 km/hr/s and 5 km/hr/s

c. 65 km/hr/s and 5 km/hr/s d. 5km/hr and 5km/hr

27. As you can see in the diagrams below, each ball starts to accelerate more and more as the incline of the plane gets higher and higher. The ball accelerate if it is dropped down a wall because of _____"

a. friction b. gravity c. air resistance d. inertia.

28. If your eyes are closed, you can tell an object has moved according to its_____."

a. inertia b. force c. reference point d. or gravity.

29. In order for an automobile to accelerate while moving at a constant speed, the automobile must be _____.?"

a. moving up hill b. moving down hill c. moving in a circle d. cannot not happen

31. If a monkey travels to the moon, his *mass* will _____?

a. increase b. decrease c. stay the same d. neither

30. If an elephant travels to the moon, her *weight* will _____?

a. Increase b. decrease c. stay the same d. neither

AUTHOR'S BIOGRAPHY AND ACKNOWLEDGEMENT

Sara Kwitek obtained a Bachelor of Science in Elementary Education with a minor in Physics from the State University of New York at Buffalo. I became very interested in the field of Physics after teaching one full year of middle school physical science. I returned back to the State University of New York at Buffalo to complete an Master of Science in Physics Education.

I would like to thank Kathleen Falconer, and Dr. Joseph Zawicki for their help in analyzing data. In addition I'd like to thank Drs Daniel MacIsaac, Dewayne Beery, and David Henry for teaching me some of the most effective methods of teaching physics in a classroom which inspired me to write this paper.

BIBLIOGRAPHY

1. Glencoe Physical Science. Ohio: McGraw-Hill, 1997. 89-91

2. Hestenes, D. (1996). "Modeling methodology for physics teachers." Proceedings of the International Conference on Undergraduate Physics Education, 1-21.

3. Hestenes, D., & Halloun, I. (1995). "Interpreting the force concept inventory." The Physics Teacher 33 502-506.

4. Hewitt, P. (1998). Conceptual Physics. 8th ed. San Francisco: Addison-Wesley, 1998. 18-35

5. New York State. The State Education Department. Intermediate Level Science Core Curriculum. Grades 5-8. By the State Education Department. 1996.

6. Wagner, J., & Fiero, A. Intermediate Level: Science Big 8 Review. New York: N & N Publishing Company, Inc, 2001. 213-223.

7. Wells, M., & Hestenes, D. (1995). "A modeling method for high school physics instruction." Am. J. Phys. 63, 606-619.