

THE EFFECT OF THE CONCEPTUAL CHANGE MODEL  
ON MISCONCEPTIONS IN 9<sup>TH</sup> GRADE PHYSICS

by

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## ABSTRACT

Overcoming students' misconceptions is a real problem for science teachers. Much of what we understand about the world comes from personal experience and if that experience led to an incorrect conception, then that incorrect conception can be very hard to overcome. This study aims to help determine if using the Conceptual Change Model can help students overcome misconceptions better than a traditional teaching approach. Two units were compared. One was taught using the conceptual change model and one using the traditional model of teaching. Students were given a pre- and post-test of conceptions for each unit, a pre- and post-survey of attitudes and pre- and post-interviews were conducted. Results indicated a small difference between the improvement of scores for the two unit. The unit taught with the Conceptual Change Model resulted in a slightly larger increase in scores than the unit taught using traditional methods.

## INTRODUCTION AND BACKGROUND

I remember my high school science teacher holding up two balls and then showing us that one was heavy, and one was light. Then she asked us which would hit the ground first. I remember being sure that the heavier one would hit the ground first. It did not. Although I was not aware of it then, my science teacher was employing parts of the conceptual change model to help me overcome my misconception. The Conceptual Change Model is a strategy that “helps students to become aware of their private views and to confront them” (Stepans, 2006, p. 6).

It wasn't until I was an undergraduate student that I realized what had happened and my battle with common science misconceptions began. Over the years, I have worked hard to help my students learn and change their understanding. However, after a decade in the classroom, I have reached the conclusion that it is hard for learners to overcome misconceptions. When working with my students, I have found that one of the most common misconceptions is the idea that weight and mass are the same. I realize that this is due in large part to the way we use the terms in everyday life. To find the mass of an object you weigh it; we associate our weight with the size of our bodies. Because we have such a concrete connection between the words weight and mass, getting students to understand that they are not the same is a major challenge. People are very committed to their misconceptions because misconceptions have been developed from personal experiences. This is one of the main reasons why misconceptions are so hard to overcome. Because they are created by the students experiences they feel very real, often more real, than the ideas presented by the teacher. For example, looking back at the

falling objects, if you were to knock a piece of paper and a pencil off the table, the pencil hits the ground first. When you pick them up, the paper is lighter; leading to the creation of a misconception. The lightness of the paper is the obvious difference between the paper and pencil and thus is the foundation for the belief that a pencil hits the ground first because it is heavier.

I currently teach at the Manson Northwest Webster Junior/Senior High School (MNW) in Manson, Iowa. Manson Northwest Webster Community School District has 328 students in the middle school and high school building. We have an 11:1 student-teacher ratio. The student body consists mainly of white students, who comprise 97.6% of the student population with the remaining 2.4% of our students being other races (D. Hock, personal communication, October 12, 2017). The school district has 33% of students on free and reduced lunch programs (D. Wood, personal communication, October 12, 2017). The students at MNW have a wide range of ability levels, and since all students take a science class their 9<sup>th</sup> grade year I feel that this is the most representative group to work with. Manson Northwest Webster also has a very supportive and cohesive staff, I have a very good support system in place to help me complete my action research project.

My experience with misconceptions led to this study. In this study, I aim to answer the question: Will using the Conceptual Change Model help 9th grade students to overcome their physics misconceptions? The additional sub questions below will help me to better understand my primary question:

1. Do misconception probes allow students to engage in the first step of the Conceptual Change Model by having “Students become aware of their own preconceptions about a concept by thinking about it and making prediction (committing to an outcome) before an activity begins” (Stepans, 2003, p. 7)?
2. Does the Conceptual Change Model improve student attitudes about science?

### CONCEPTUAL FRAMEWORK

The Oxford Dictionary online says that a misconception is “a view or opinion that is incorrect because based on faulty thinking or understanding” (Misconception, 2017). This definition is important because it uses the wording faulty thinking. Misconceptions are not a lack of knowledge but rather they are incorrect knowledge or understanding. This incorrect knowledge that students develop is based on personal experiences. In an example modified from *The Physics Classroom* (2016), a person might drop a feather and a penny and they see the penny hits the ground first, because of this observation they deduce that the penny falls faster because it is heavier than the feather. The incorrect conception that is the source of a misconception is supported through the person’s life with many repeated experiences that tell the person that they are correct. Then, when that individual takes high school physics and learns that due to Earth’s gravity all things fall at the same rate, they are faced with conflicting conceptions: the one that is correct and the one that is based on experience. The answer based on experience receives more weight and the students will often fall back to that conception although it is incorrect

(Eaton, Anderson, & Smith, 1983). Research suggests that it is very difficult to change the conceptions of students, especially if they differ dramatically from the explanations presented by their teachers. Therefore, restructuring student's knowledge is necessary to overcome misconceptions (Chi, Slotta, & de Leeuw, 1994). In fact, even with instruction most students won't give up on their misconception entirely. Rather, "they change their mental models in a way that allows them to retain as many as possible of their experiential beliefs without contradicting adult teachings" (Vosniadou, 1992, p. 352), meaning they reinforce their misconceptions by adding to them what they consider to be the correct scientific explanations.

One instrument used to identify students' understanding of correct science explanations in physics is the Force Concept Inventory (FCI). The instrument is used to assess students' understanding of force and illustrates misconceptions (Hestenes, Well & Swackhammer, 1992). The FCI is most commonly given as a pre and posttest, at the beginning and end of a course or unit. Students who have overcome their misconceptions through instruction tend to score higher on the post-test than on the pre-test.

One example of the use of the FCI was conducted with 20 secondary science girls in Somayeh High School in Tehran, Iran. The goal of the study was to determine if traditional instructional methods resulted in changing misconceptions identified by the FCI. The results indicated that traditional teaching methods were not effective in correcting misconceptions related to force as identified by the FCI (Fadei & Mora, 2015).

There are several ways to deal with misconceptions. The results of a meta-review of misconception research articles, it was determined that misconceptions are something

teachers should be concerned about because misconceptions are difficult to correct. However, when researchers looked at the data provided in the review, they show that students keep missing the same questions regardless of age. This is verified by many different researchers; misconceptions are real and they will not go away on their own. There is no simple answer to the question of what to do about misconceptions, but present research by several researchers suggests that to overcome misconceptions we need to approach learning science in a conceptual manner. They then go on to say that they do not think that conceptual change is possible without methodological change. In their opinion, the teaching must be explicit and focus not just on the what, but also the how of science (Gil-Perez & Carrasosa, 1990).

One group of researchers wanted to see the effect of group work on misconceptions of 9<sup>th</sup> grade students learning about Newton's Laws. Their goal was to place students in groups of two and allow them to work through activities that included worksheets, concept cartoons, case studies, writing a story, dramatization, debates between groups and performance homework and experiments. After they had finished their activities, students presented their results to their peers. Students were given a pre- and a post-test to compare their misconception before and after the instruction. The results of the comparison between pre- and post-tests for the experimental group showed that for each misconception tested there was a small but significant drop in the number of students with that misconception. The researchers reflected that in some cases where students were working in groups, collaboration may have led to strengthening of the misconception. The trend was especially strong if one student presented the

misconception with a compelling argument and the partner did not argue to the contrary. They made it clear that the teacher needs to keep a close eye on the groups to prevent this type of thing from happening. According to the author, for teachers who want to apply this method, the appropriate order is to first focus on conceptual teaching and hands on activities, and then move on to examples that have numbers (Ergin, 2016).

To change misconceptions, teachers need a concrete plan that will lead to a conceptual change. The Conceptual Change Model is a framework for teaching science, specifically with the goal of overcoming misconceptions (Stepans, 2003). Investigations such as “A Private Universe” have highlighted students’ misconceptions around universal topics such as seasons (Schneps & Sadler, 1987). The video shows how Harvard graduates have essentially the same misconceptions as 9th graders. This demonstrates a need for a new approach to teaching and learning. The Conceptual Change Model is the answer to the problem. Posner, Strike, Hewson and Gertzog (1982) and Strike and Posner (1985) outline the conditions necessary for a conceptual change to occur:

- One, the students must be dissatisfied with their existing views.
- Two, the new concept must appear somewhat plausible.
- Three, the new concept must be better or more attractive in some way.
- Finally, the new concept must have the power to explain and predict future events (Stepans, 2003, p.6).

Conceptual Change Model (CCM) helps a teacher to meet the conditions necessary for conceptual change. The CCM incorporates six phases into lessons that will

allow a student to examine and change their current conception. The six parts of the

CCM requires:

1. Students become aware of their own preconceptions about a concept by thinking about it and making predictions (committing to an outcome) before an activity begins.
2. Students expose their beliefs by sharing them initially in small groups and then with the entire class.
3. Students confront their beliefs by testing and discussing them in small groups.
4. Students work toward resolving conflicts (if any) between their ideas (based on the revealed preconceptions and class discussion) and their observations, thereby accommodating the new concept.
5. Students extend the concept by trying to make connections between the concept learned in the classroom and other situations, including their daily lives.
6. Students are encouraged to go beyond, pursuing additional questions and problems of their choice to the concept. (Stepans, 2003, p. 7)

Stepans (2003) explains how to use the materials provided and that when looking at a time frame the best way to determine how long is enough is to spend as much time as necessary. As with all teaching, the goal when using CCM should be to uncover student understanding not cover material. Since there will always be a conflict between teachers and time, it is up to each individual teacher how best to balance uncovering student understanding and covering material.

The final step of the CCM is assessments, which are viewed as an important part of the learning process and that help align student expectations, student experiences and assessment. While there is no single way to assess student understanding, strategies such as interviewing, observation, performance assessments, projects and pen and paper tools are effective. If teachers align their instruction with their assessments and use a variety of assessment strategies, then the assessment will be an accurate reflection of their students understanding (Stepans, 2003).

There has been a lot of research on how the Conceptual Change Model helps students to overcome misconceptions. Akbas and Gencturk (2011) explored the effect of conceptual change approach to eliminate ninth grade high school students' misconceptions about air pressure. They used the Conceptual Change Model as well as texts and concept maps specifically designed to help students to change their conceptions. They had 45 control students and 45 students who received the conceptual change materials. Students were given a pre-and post-test to see if their misconceptions had changed. The results showed that using the Conceptual Change Model and conceptual change materials were more effective than traditional methods. It was observed that during the testing, some new misconceptions occurred and some of the misconceptions increased. It was also observed that a student's prior misconceptions can cause that student to form more misconceptions. The students used the old conception to understand and create their new understanding and if the old conception is faulty then the new conceptions will be faulty as well and a misconception is created. They suggest that it is important to know what your student's misconceptions are before you teach them so that you can avoid any adding of misconceptions.

#### METHODOLOGY

This study implemented the Conceptual Change Model to help students overcome misconceptions in a unit of motion and forces. The Motion and Forces Unit was then compared to a unit on chemical reactions to see if there were fewer misconceptions at the end of a unit that was taught using the Conceptual Change Model. The research methodology for this project received an exemption by Montana State University's

Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The unit on motion and forces that I taught my physical science students took 13 days to complete (Appendix B). This unit covers basic Newtonian physics. My class was at the Manson Northwest Webster High School in Manson, Iowa. There were 39 students of which 18 were male, and 21 were female, 36 of these students were in ninth grade and three were in eleventh grade. This was a mixed group of students with some high achieving, some average, and some who are repeating the course due to academic or behavioral challenges. As a result, they are very mixed in their attitudes about school; some are very interested in their learning while others are just trying to get through. There was no ethnic diversity in this class; it was composed entirely of white students. As for the culture of the school, I feel that as a whole the culture of learning could use an improvement. Most students try to get by with as little effort as possible and seemed to find little value in learning.

The Motion and Forces Unit was taught using the Conceptual Change Model (CCM), the goal was to help students overcome their misconceptions. I used the Force Concept Inventory (FCI) as a pretest to see what misconceptions students had (Appendix C). The results of each student's test were compared to the FCI posttest and analyzed using a normalized gain statistical analysis and a t-test. The results were reported in box and whisker plots.

Then students were given the Test of Science Related Attitudes (TOSRA) to determine student attitudes (Appendix D). The TOSRA utilized a Likert scale where

students could strongly agree, agree, take a neutral stance, disagree or strongly disagree with each statement. This survey was administered using a Google form. The results of each student's survey were compared to the TOSRA post-survey. The TOSRA is scored with five points awarded to strongly agree, four for agree, three for neutral, two for disagree, and one for strongly disagree. Half the questions have a reverse score of one point awarded to strongly agree, two for agree, three for neutral, four for disagree, and five for strongly disagree. Scores are summed, and then 50 points are subtracted. Higher scores indicate a more positive attitude related to science, with the maximum score being 200 and the minimum score being zero. The TOSRA responses were analyzed for themes and frequency. They were also analyzed using a t-test to see if a statistical difference existed between the pre-test and post-test scores.

Additionally, three students were chosen at random to be interviewed. These interviews were conducted via the FlipGrid platform and consisted of three questions from Waller's Interview Questions (Appendix E).

Then I chose misconception probes based on the most common misconceptions. The misconceptions that were identified by the FCI were on the topics of Newton's First law, Newton's second law, Newton's third law, and gravity (Appendix F). The probes allowed students to work through the first two steps of the CCM, committing to a position and exposing beliefs. The basic format for the unit was at the start of a concept students were given a misconception probe. This allows students to commit to a position and expose their beliefs. Once the beliefs were exposed, students were given an activity to help them to confront their beliefs. Then, as a class, we engaged in direct instruction

and discussion to accommodate the concept. Finally, depending on the concept, a short writing assignment or additional conceptual practice was given to go beyond. For example, one of the misconceptions was that weight affects how fast objects fall. Students were given the misconception probe, “Which Will Hit the Ground First?” The students were asked to pick which will hit the ground first: a heavy steel ball or a light wooden ball. Students were able to pick the steel ball, the wooden ball or that they will both hit the ground at the same time. They were also required to write an explanation of their beliefs. Then they were given the activity “Which Will Fall Faster an Elephant or a Mouse?” which has students compare sponges and blocks of wood of equals sizes and then compare those to a sheet of paper and a wadded-up ball of paper (Appendix G). At that point, I provided direct instruction on gravity and free fall. Finally, students were given a writing assignment that required them to use the Claim Evidence Reasoning Framework (CER) to construct a scientific argument that answers the question: “Which will fall faster in air a small round plastic ball or a large Styrofoam block?” (Appendix H). The Claim Evidence Reasoning Framework is a system to help students explain phenomena. The CER Framework breaks explanations into three parts: the Claim, the Evidence and the Reasoning. The claim is a statement that answers the original question. The evidence section is the observations that students collected to support their claim. The reasoning is the explanation of why the evidence is the evidence to support the claim. (Appendix H).

Once the Motion and Forces Unit was completed, the FCI was given again in order to determine if students decreased their misconceptions. The TOSRA was also

given a second time to see if using the CCM improved student attitudes. To finish the Motion and Forces Unit, the three students that were initially interviewed were interviewed again using four questions from Waller's Interview Questions that were asked and answered through the FlipGrid system (Appendix E). The data from these interviews were analyzed for common themes and used as evidence to support other data analysis claims.

The Chemical Reactions Unit took 13 days to complete and was taught using traditional teaching methods, a mixture of direct instruction, practice, quizzes and labs. At the beginning of the unit, each student was given a packet of notes and practice that they would be expected to fill out over the course of the unit. In addition to the packets, one lab comparing the different types of chemical reactions, and one online simulation of balancing equations was done (Appendix J).

Before beginning the unit, a pre-test for misconceptions was given; the pre-test was created using the American Association for the Advancement of Science (AAAS) bank of questions (Appendix K). This bank of questions was written specifically to test for students' misconceptions on a variety of science topics. The results of each student's tests were compared to the AAAS post-test and analyzed using a normalized gain statistical analysis, and a t-test. The results were reported in box and whisker plots. The FCI normalized gains were compared to the AAAS test normalized gains to see if there was a greater improvement in one of the two units. A high normalized gain has a value that is greater than or equal to 0.7, a medium normalized gain is less than 0.7 and greater than or equal to 0.3, and a low normalized gain is less than 0.3 (Hake, 1998). A t-

test was run to see if there was a statistical difference between the two sets of normalized gains.

The variety of data collection tools used to answer the primary and secondary questions are outlined in Table 1.

Table 1  
*Data Triangulation Matrix*

Data Source	Questions		
	Focus Question: Will using the conceptual change model help 9th grade students to overcome their physics misconceptions?	Secondary Question: Do misconception probes allow students to engage in the first step of the conceptual change model?	Secondary Question: Does the conceptual change model improve student attitudes about learning?
Pre and Post Motion and Forces Content (FCI) Test	X		
Pre and Post Chemical Reactions Content (AAAS) Test	X		
Pre and Post Student attitudes survey			X
Interview Questions	X	X	

## DATA AND ANALYSIS

The results of the FCI pre- and post-test showed a range of scores on the pretest of 3 to 17 with a median score of six ( $N= 39$ ). The FCI post-test showed a range of scores from 3 to 29 with a median score of 10 ( $N= 39$ ). When the pre- and post-test scores were compared the lowest scores remained the same but the lowest score of the interquartile

range of the post-test scores was higher than the highest score of the interquartile range of the pretest. The normalized gain was calculated for the FCI pre-test and post-tests; this showed to be .22, which according to Hake (1998) is considered low. The normalized gain indicated a small increase in the post-test score as compared to the pre-test score (Figure 1).

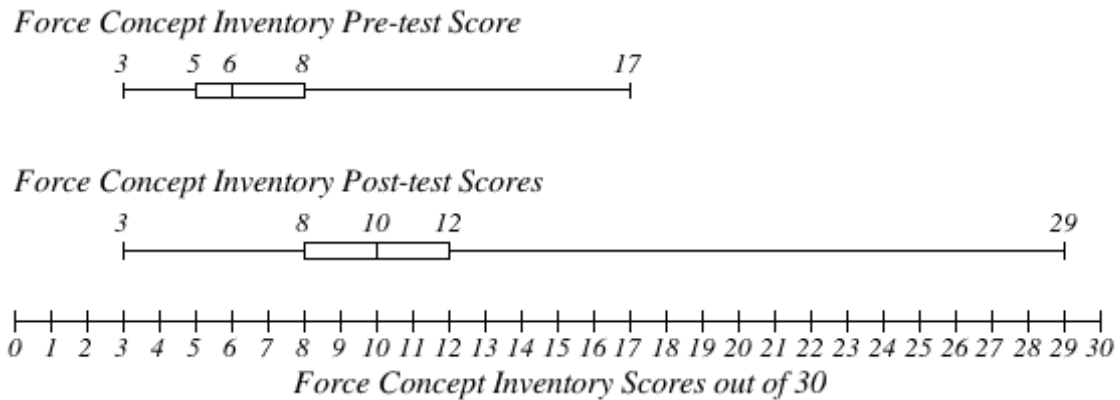


Figure 1. FCI pre- and post-test box and whisker plot, (N=39).

The FCI questions with the most correct answers were related to the topics of gravity and how objects fall (#’s 1,6,7). The questions with the fewest correct responses were on Newton’s second law, friction, and projectile motion (#’s 11, 13, 21).

Data was analyzed from the Test of Science Related Attitudes (TOSRA) survey. The results of the pre-survey show a range of scores from 46 to 148 with a median score of 90. The post-test scores show a range from 52 to 200 with a median score of 100. When the scores are compared the interquartile range of the post-test scores was smaller than the interquartile range for the pre-test scores, and the post-test had a higher maximum score (Figure 2).

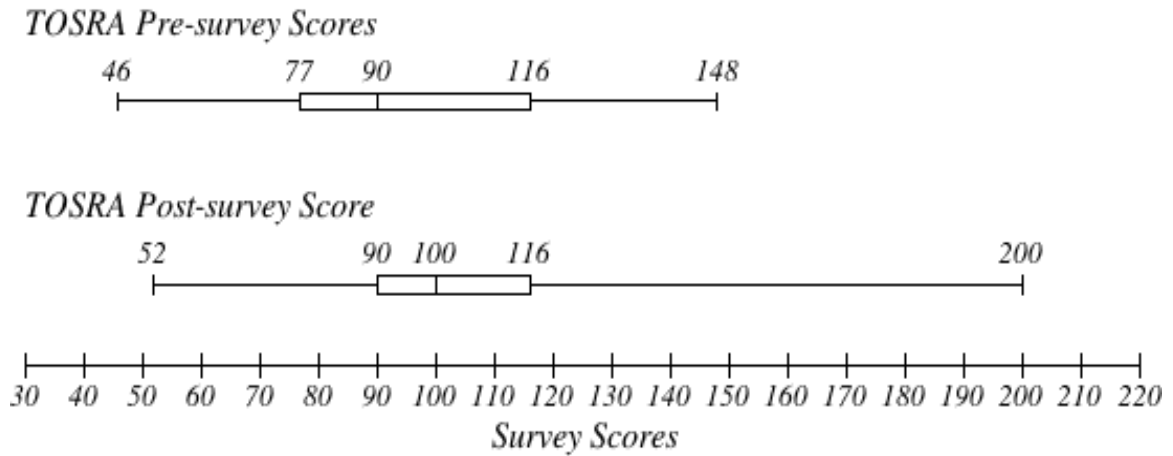


Figure 2. TOSRA pre- and post-survey box and whisker plot, ( $N=39$ ).

The TOSRA pre- and post-survey results were broken into the five main categories and the scores for each were put into a box and whisker plot. The category “career interest in science” had the greatest increase score, followed by “attitudes to scientific inquiry.” The category that had the lowest score was “enjoyment of science lessons.” All the categories had a similar interquartile range and all but “leisure interest in science” showed very little shift in scores of the interquartile range. “Leisure interest in science” showed a larger decrease in the interquartile range than the other categories. “Attitude to scientific inquiry,” “adoption of scientific attitudes,” and “enjoyment of scientific lessons,” had a shift in interquartile range of one point. The interquartile range for “career interest in science” decreased by approximately one point, and the interquartile range for “leisure interest in science” changed by three points.

The next analysis was done to two statements from each category, one positive and one negative. The statements chosen are considered to be representative of the category as a whole (Table 2 and 3).

Table 2

*Table of Positive Statements Chosen to Represent Each Category*

Category	Statement
Attitude to scientific inquiry	I would prefer to find out why something happens by doing an experiment than by being told (#3).
Adoption of scientific attitude	I am curious about the world we live in (#18).
Enjoyment of science lessons	Science is one of the most interesting school subjects (#33).
Leisure interest in science	I would enjoy visiting a science museum at the weekend (#62).
Career interest in science	I would like to be a scientist when I leave school (#70).

Table 3

*Table of Negative Statements Chosen to Represent Each Category*

Category	Statement
Attitude to scientific inquiry	I would rather find out about things by asking an expert than by doing an experiment (#38).
Adoption of scientific attitude	Finding out about new things is unimportant (#25).
Enjoyment of science lessons	I dislike science lessons (#12).
Leisure interest in science	I get bored when watching science programs on TV at home (#13).
Career interest in science	I would dislike being a scientist after I leave school (#7).

When the pre-survey positive statements responses were analyzed for frequency it was observed that a majority of students chose neutral, agree, or strongly agree. The statement that most students agreed with or strongly agreed with was “I am curious about the world we live in” (#18). The statements with which most of the students disagreed or strongly disagreed was, “I would like to be a scientist when I leave school” (#70). A higher percentage of agree and strongly agree responses were recorded for the categories of attitude to scientific inquiry and adoption of scientific attitudes. The other

three categories had a higher percentage of disagree and strongly disagree responses. When the post-survey statements responses were analyzed for frequency it was observed that for the statement, “I would like to be a scientist when I leave school” (#70), there was an increase in the responses agree and strongly agree. This was the largest change in frequency of all the positive statements examined. For the statement, “I am curious about the world we live in” (#18), the number of agree and strongly agree responses decreased by a very small amount. “I am curious about the world we live in” (#18), also had the lowest frequency of disagree and strongly disagree responses. For the statements, “I would prefer to find out why something happens by doing an experiment than by being told” (#3), “science is one of the most interesting school subjects” (#33) and “I would enjoy visiting a science museum at the weekend” (#62), the number of agree and strongly agree responses decreased by a more noticeable amount (Figure 3).

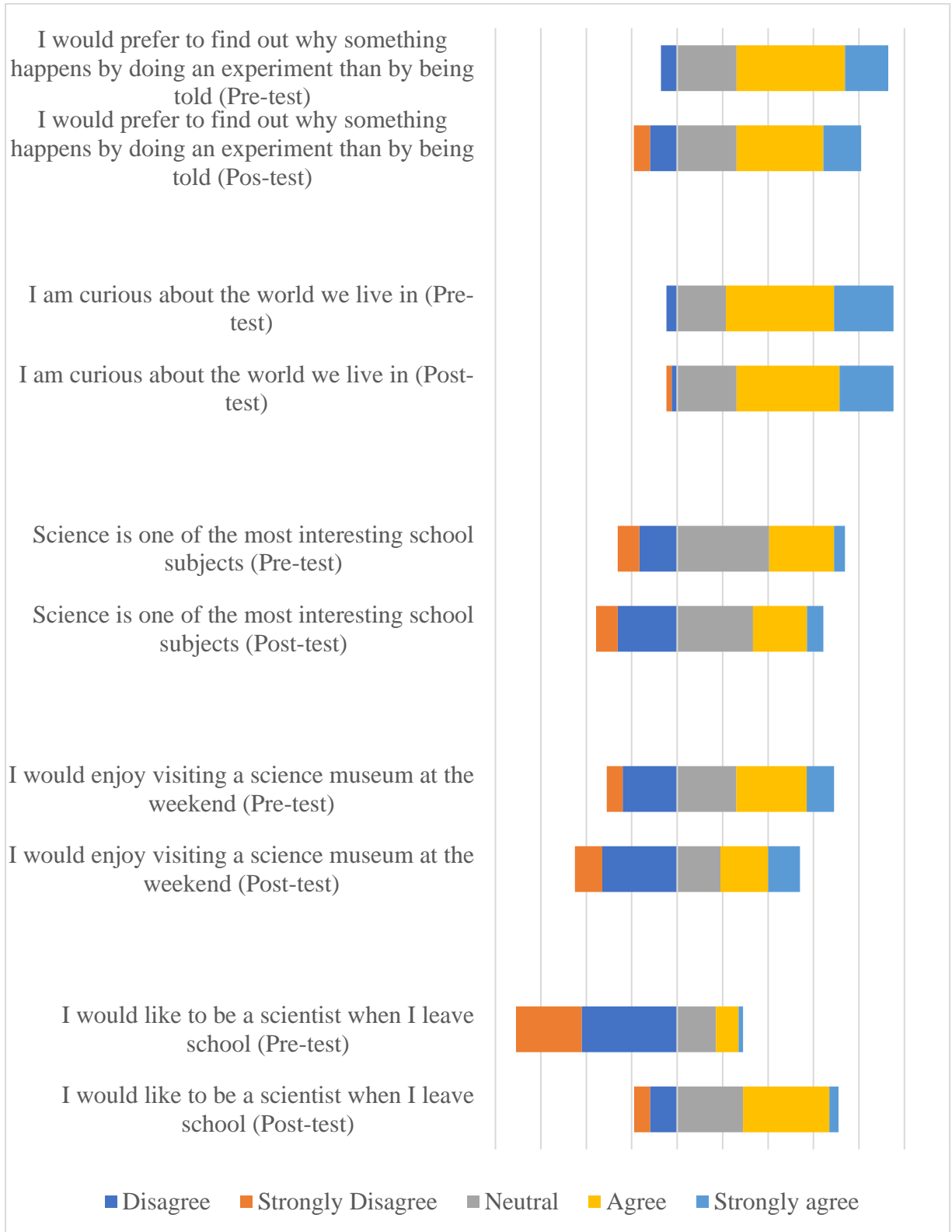


Figure 3. Graphs of frequency of responses to positive statements, (N=39).

When the negative statements were analyzed it is important to note that a desired response to the negative statements would be opposite of those for positive statements. A desired response to the statement, “I dislike science lessons” (#12), would be strongly disagree. In this case we see that there are increases in the number of disagree and strongly disagree statements for all but, “finding out new things is unimportant” (#25). For all negative statements neutral responses occurred almost as frequently than they did for the positive statements. The statement with the highest frequency of strongly disagree and disagree was “finding out new things is unimportant” (# 25), even though the frequency of desirable answers dropped in the post-test, the decreased results were higher than any of the other statements. One student when asked what they were most excited to learn about said, “nothing exact, I just like learning new things.” The same student when asked what they enjoyed most about this unit said, “all the hands-on labs, it was more fun to learn new things by doing stuff.” The statements that had the lowest frequency of strongly disagree and disagree was, “I dislike science lessons” (#12) and the pre-survey score for, “I would rather find out about things by asking an expert than by doing an experiment” (#38), this makes sense as one student explained when asked what they enjoyed most about this unit said, “nothing, you did too many labs and didn’t tell us the answers, that makes it too hard” (Figure 4).

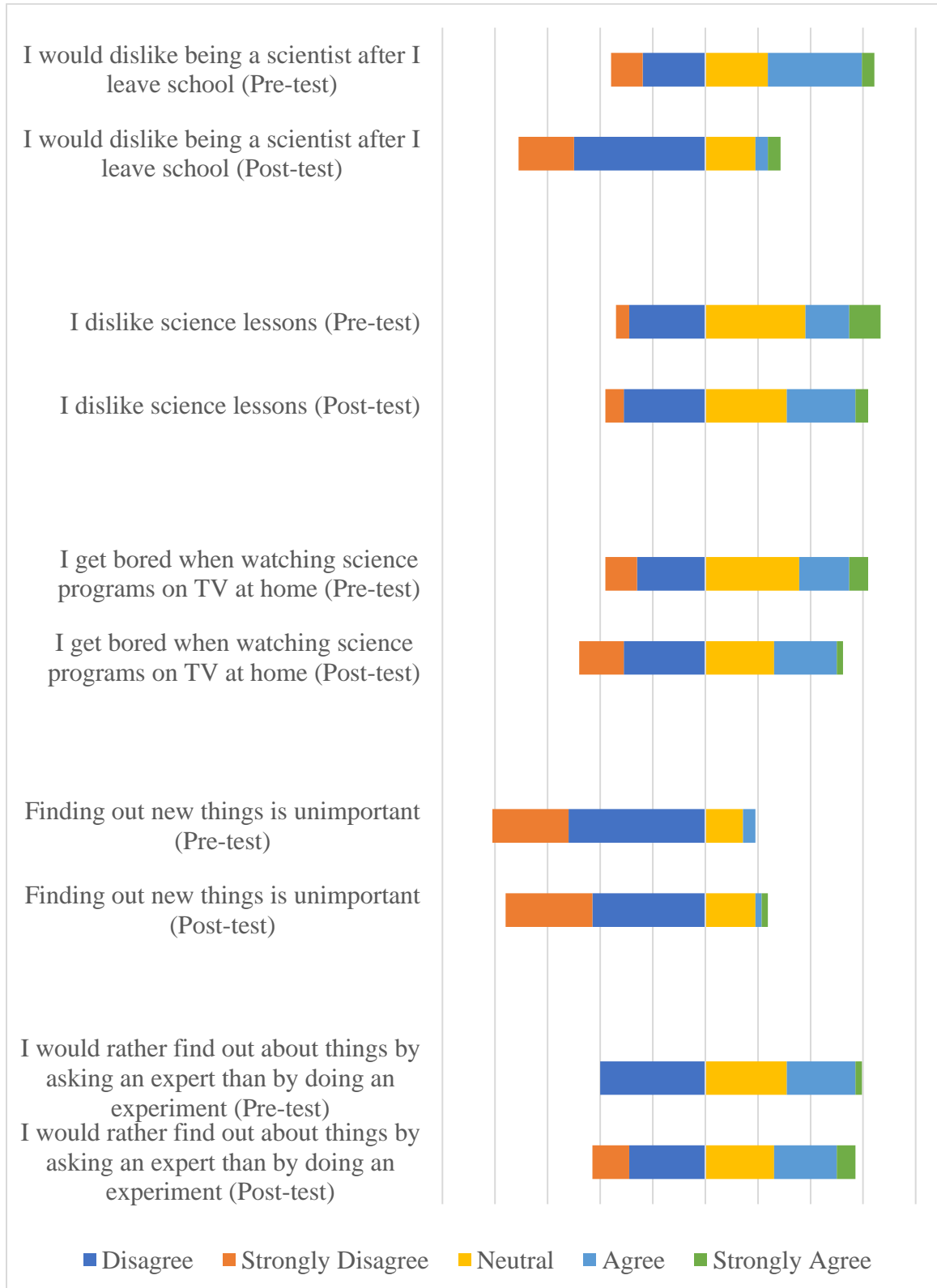


Figure 4. Graphs of frequency of responses to negative statements, (N=39).

One way students understanding was assessed during the Motion and Forces Unit was students were asked to complete a Claim Evidence and Reasoning Framework for the question “Which will fall faster in air a small plastic ball or a large Styrofoam block?” After completing a discussion over Newton’s second law, students consistently answered the question correctly by claiming that the heavier block will hit the ground first. Additionally, many students were able to back up their claim with evidence, and some were able to explain the reasoning behind the evidence using Newton’s second law. In the example of student work shown below, the student has a clear claim and uses evidence and reasoning to back up their claim (Figure 5).

The students used the slope of the best fit line to determine the acceleration ( $\Delta v/\Delta t$ ) of each object. After looking at the results, one of the students remarked, "Wow, both objects had an acceleration of  $9.8 \text{ m/s}^2$ . That's exactly the acceleration due to the force of gravity on the surface of the Earth. I wonder what the accelerations of the objects would be if they were falling through air."

**Scientific Question:** Which of the two objects do you predict would have the greater acceleration when dropped in air?

I think the ball will have the greater acceleration when dropped in the air.

The block is bigger and heavier. It is 5 inches long and has a mass that is 4 times more than the ball. The ball is 3 inches around. When dropped in a vacuum both balls hit the ground at the same time.

When objects are dropped in air they no longer fall with the same acceleration, because air resistance is a type of friction that pushes against the objects. Newton's 2nd law explains that the bigger the force the more it changes the objects motion. The object that is bigger is going to be pushed more. This push is against gravity. So objects that are bigger will fall slower.

Figure 5. Example of student CER work.

Finally, analysis was done using the AAAS Chemical Reactions pre- and post-test data ( $N=39$ ). The AAAS test contained 26 questions on the nature of chemical reactions

and conservation of matter. The results showed a range of scores on the pre-test of four to twenty-three with a median score of ten. The AAAS post-test showed a range of scores from four to twenty-five with a median score of thirteen. The interquartile range increased dramatically between the pre and post-test. The upper quartile of the post-test scores was larger than the whole interquartile range of the pretest. The average normalized gain was calculated for the AAAS pre-tests and post-tests; this showed to be .20. This value is considered low. The normalized gain indicated a small increase in the post-test score as compared to the pre-test score (Figure 6).

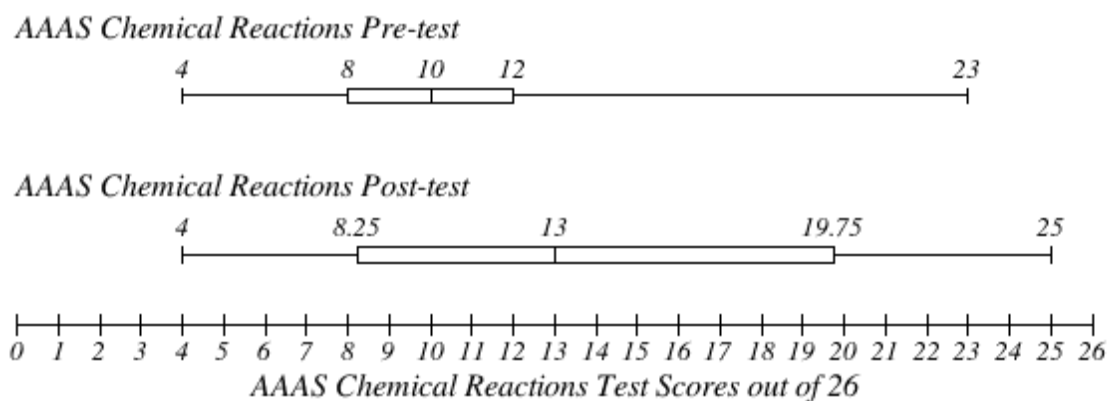


Figure 6. AAAS Chemical Reactions pre- and post-test box and whisker plot, ( $N=39$ ).

The AAAS question with the most correct answers was related to the topic of products of chemical reactions (#4, and 15) with 30 correct responses each. These questions were related to the topic of products of chemical reactions. The question with the fewest correct responses was on the topic of conservation of matter, (#17) with nine correct responses.

The last method for analyzing the AAAS and FCI test data was the Wilcoxon Signed Rank Test ( $N=39$ ). In this test, I compared the normalized gains for the AAAS and the FCI to see if there was a significant difference in gains. The results showed the

W-value is 24. The critical value was 271. If the W-value is less than the critical value, then we reject the null hypothesis. The null hypothesis states that there is no difference between the two sets of normalized gains. Since the W-value is lower than the critical value, there is a significant difference between the AAAS normalized gains and the FCI normalized gains. This is consistent with the results observed when comparing the average normalized gains for the FCI and the AAAS scores. Both tests show an improvement in scores and that the FCI scores improved more than the AAAS.

#### INTERPRETATION AND CONCLUSION

My primary question was “Will using the conceptual change model help 9<sup>th</sup> grade students overcome their physics misconceptions?” The pre-test vs. post-test data collected suggested meaningful positive growth in student learning of motion and forces and chemical reactions. For example, looking at the average normalized gain for the Motion and Forces unit, which was taught using the Conceptual Change Model, the data shows a score of .22 which is a small but measurable positive improvement of understanding. The average normalized gain for the Chemical Reactions Unit, which was taught using traditional methods, was .20 which is also a small but measurable improvement. The normalized gains for the Chemical Reactions Unit were slightly lower than the improvement for motion and forces. Misconceptions are very hard to overcome, and these data show that the Conceptual Change Model has a small benefit in overcoming misconceptions. When asked “How do you feel about using the conceptual change model in class, do you feel that it helps you learn?” one student reflected, “it helps me figure out what I’m doing wrong but, I would like it better if you just told me the

answers.” Another student was more enthusiastic with a response of, “Yes, I love doing hands-on work, I didn’t really think I liked science, but this is fun!”

In the future, I would like to use the AAAS test of motion and forces for my pre- and post-test of conceptions for the Motion and Forces Unit. This tests for a smaller number of misconceptions and contains questions that are worded more similarly to the AAAS Chemical Reactions test. I believe that this would show more accurately the improvement using the CCM. The FCI tests for 30 different misconceptions related to motion and forces and the AAAS tests for 20 different misconceptions related to chemical reactions and conservation of matter. I focused on nine misconceptions for the Motion and Forces Unit and five misconceptions in the Chemical Reactions Unit. I would like to compare these units more evenly in the future to better show how well the Conceptual Change Model works on misconceptions. I would also be interested in giving my students the post-test again at the end of the school year to see if they retained the post-test gains for if one model showed improved retention of information over the other.

My first sub-question was “Do misconception probes allow students to engage in the first step of the Conceptual Change Model by having students become aware of their preconceptions about a concept by thinking about it and making predictions (committing to an outcome) before an activity begins (Stepans 2006, p. 7)?” The results of the motion and forces test show that the questions that had the most common correct answers on the posttest were to questions that were on the same topics as misconception probes that we conducted. The first question of the FCI had the most correct answers and was worded very similarly to the misconception probe given to students. When asked, “Do you feel

that the misconception probes helped you identify the ideas you were understanding incorrectly?” many students answered with an affirmative. One student commented, “it was pretty frustrating to keep getting the answers wrong.” While another noted, “that if I know I’m wrong now maybe I won’t get the wrong answer on the test.” Additionally, I noticed that the most common question missed on the AAAS test was on the topic of conservation of matter; this was a concept that was emphasized during traditional instruction, but no misconception probe was used to reveal the misconception to the students. As a result, fewer students were able to overcome that misconception.

Also, when students were asked, “Based on the learning targets posted for the upcoming unit, do you feel like there are any concepts in the upcoming unit that you do not understand correctly?” One student responded, “No, I might not know everything yet, but know I understand right.” There was an interesting connection between students that felt a lot of confidence about their understanding and their scores on the FCI.

Anecdotally, students with high confidence did not seem to have as high of scores as those who were less confident in their understanding. It would be interesting in the future to see if a connection exists between confidence and student’s ability to overcome misconceptions.

The second sub-question I posed was, “Does the Conceptual Change Model improve student attitudes about science?” Based on the results, I would say the answer to this question is not by a measurable amount. Students seem to hold on to their opinions about things more strongly than their misconceptions. There was some shift in the third quartile of scores with at least one student having changed their attitudes, but the first

quartile scores change very little, and interquartile range shifted very little. When the parts of the TOSRA were examined by section, some positive shifts in attitude were observed but also some negative shifts. The overall shift was positive but to a very small degree.

### VALUE

This study was about more than just implementing the Conceptual Change Model (CCM). The purpose of any change to a curriculum is to improve student understanding of the content. Overcoming misconceptions is very challenging and complex. It can be very difficult to replace the incorrect explanations that students develop. This project involved expanding my understanding of how my students learned and how the CCM helps students to form new correct conceptions. In addition to looking at concept learning, I was also interested in student attitudes, and this project taught me that attitude has a direct impact on achievement. This project helped me to deepen my teaching skills by forcing me to evaluate how I have my curriculum organized. Also, this project helped me to see more clearly how what I do directly affects what my students learn. I feel that this project more than any other part of my graduate education allowed me to grow professionally and gain new skills as a teacher.

During this project, I learned that the CCM works to help students overcome misconceptions but that traditional teaching also has an impact on changing conceptions. I learned that using the misconception probes as part of the CCM was one of the most effective tools in overcoming misconceptions. Students really enjoyed the discussion and demonstrations that came after the misconception probes and their improvement on these

concepts in the testing was noticeable. I learned that the CCM didn't change my student attitudes, but that my students value learning and enjoy experimenting with hands-on materials. My students also really enjoyed the interview portion, in which they found a fun and creative way to give me feedback. I learned a lot about what they were taking away from the lessons by their responses to the interview questions. Finally, I learned that this project has created as many questions for me as it has answered. I will continue to use the CCM in my future lessons, and I will modify my methodology to achieve the results I am interested in, and to answer the questions that have been generated in this project.

Perhaps the most valuable part of this project was the knowledge that I can make positive changes in my own classroom. Learning how to systematically plan and conduct research in my own classroom will allow me to continue to grow and develop as a teacher. Additionally, I also learned how much information can be gathered about student understanding in the form of a simple pre-test. If students already understand a concept, it is not important to teach it no matter how fun or interesting the topic. Knowing what they don't know and how they are misunderstanding a topic can allow you to do a better job of structuring your lessons to help them overcome those misconceptions.

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APPENDICES

APPENDIX A  
INSTITUTIONAL REVIEW BOARD EXEMPTION



**INSTITUTIONAL REVIEW BOARD**  
**For the Protection of Human Subjects**  
**FWA 00000165**

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*Chair:* Mark Quinn  
 406-994-4707  
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**MEMORANDUM**

**TO:** Jessica Waller and John Graves

**FROM:** Mark Quinn *Mark Quinn CJ*  
 Chair, Institutional Review Board for the Protection of Human Subjects

**DATE:** November 9, 2017

**RE:** "The Effect of Conceptual Change Model on Misconceptions in 9th Grade Physics" [JW110917-EX]

The above research, described in your submission of November 9, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

UNIT OUTLINE FOR MOTION AND FORCE UNIT

## MOTION AND FORCES UNIT OUTLINE

DAY	INSTRUCTIONAL OBJECTIVE	HOMEWORK/PRACTICE
DAY 1	SPEED NOTES	PRACTICE PAGE 1-3
DAY 2	GRAPHING SPEED	PRACTICE PAGES 4-6
DAY 3	ACCELERATION	PRACTICE PAGE 7-9
DAY 4-5	GO OVER PRACTICE SPEED AND ACCELERATION LAB	CONCLUSION QUESTIONS
DAY 6	GO OVER CONCLUSION ?S NEWTON'S 1 <sup>ST</sup> LAW PROBE (#20,21,24) NEWTON'S 1 <sup>ST</sup> LAW LAB	CONCLUSION QUESTIONS
DAY 7	GO OVER CONCLUSION ?S NEWTON'S 1 <sup>ST</sup> LAW NOTES	PRACTICE PAGE ---
DAY 8	GO OVER PRACTICE NEWTON'S 1 <sup>ST</sup> LAW CONCEPTIONS JIGSAW	
DAY 9	NEWTON'S 2 <sup>ND</sup> LAW PROBES K'NEX LAB	CONCLUSION QUESTIONS
DAY 10	GO OVER CONCLUSION ?S FRICTION PROBE FRICTION LAB	CONCLUSION QUESTIONS
DAY 11	GO OVER CONCLUSION ?S GRAVITY PROBES GRAVITY LAB	CONCLUSION QUESTIONS
DAY 12	GO OVER CONCLUSION ?S NEWTON'S 2 <sup>ND</sup> LAW NOTES	PRACTICE PAGE
DAY 13	GO OVER PRACTICE NEWTON'S 2 <sup>ND</sup> LAW CONCEPTIONS JIGSAW	CER WRITING ASSIGNMENT
DAY 14	NEWTON'S 3 <sup>RD</sup> LAW PROBE NEWTON'S 3 <sup>RD</sup> LAW LAB: TUG-O- WAR	CONCLUSIONS QUESTIONS
DAY 15	GO OVER CONCLUSION ?s NEWTON'S 3 <sup>RD</sup> LAW NOTES INTRODUCE THE MOUSE TRAP CAR PROJECT	PRACTICE PAGE
DAY 16	GO OVER PRACTICE MOUSE TRAP CAR WORKDAY	PROJECTS DUE ___DAYS
DAY 17	WORKDAY	

APPENDIX C  
FORCE CONCEPT INVENTORY

Revised form 081695R

## Force Concept Inventory

Originally published in *The Physics Teacher*, March 1992

by

*David Hestenes, Malcolm Wells, and Gregg Swackhamer*

Revised August 1995

by

*Ibrahim Halloun, Richard Hake, and Eugene Mosca*

The Force Concept Inventory (FCI) is a multiple-choice "test" designed to assess student understanding of the *most basic* concepts in Newtonian mechanics. The FCI can be used for several purposes, but the most important one is to *evaluate the effectiveness of instruction*.

For a full understanding of what has gone into development of this instrument and how it can be used, the FCI papers (refs. 1, 2) should be consulted, as well as: (a) the papers on the FCI predecessor, the Mechanics Diagnostic Test (refs. 3, 4), (b) the paper on the Mechanics Baseline Test (ref. 5), which is recommended as an FCI companion test for assessing quantitative problem solving skills, and (c) Richard Hake's paper (ref. 6) on data collection on university and high school physics taught by many different teachers and methods across the U.S.A.

Refs. 1-5 are online at <<http://modeling.asu.edu/R&E/Research.html>> Ref. 6 is online as ref. 24 at <<http://www.physics.indiana.edu/~hake>>.

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1. D. Hestenes, M. Wells, and G. Swackhamer (1992). Force Concept Inventory, *The Physics Teacher* **30**, 141-151.
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  4. I. Halloun and D. Hestenes (1985). Common sense concepts about motion, *Am. J. Phys.* **53**, 1056-1065.
  5. D. Hestenes and M. Wells (1992). A Mechanics Baseline Test, *The Physics Teacher* **30**, 159-166.
  6. R. Hake (1998). Interactive-engagement vs. traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses. *Am. J. Phys.* **66**, 64-74.
-

Teacher: these are suggested directions to give your students:

*Your participation is voluntary, but strongly encouraged.*

*Do not write anything on this questionnaire.*

*Mark your answers on the scantron*

*Make only one mark per item.*

*Do not skip any question.*

*Avoid guessing. Your answers should reflect what you personally think.*

*On the scantron:*

*Use a No. 2 pencil, and follow marking instructions.*

*Fill in your name and class period.*

*Fill in the "Exam No." given by your teacher (if any).*

*Plan to finish this questionnaire in 30 minutes.*

Notes to the Teacher:

The FCI is closed-book, no notes, no equations.

Most important! to maintain security, please don't call it the *Force Concept Inventory*; rather, give it another name (ex. mechanics survey, big force diagnostic), or no name. (This is because the original 1992 version appears on the web from time to time, unprotected. We are unable to prevent this, unfortunately.)

Make it count for a grade or extra credit, so that students will take it seriously.

Collect the test and destroy it, or keep it under lock and key, so that it doesn't get into student files.

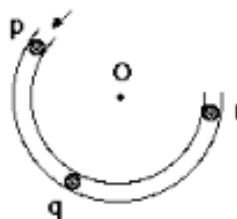
Don't photocopy this page or the first page.

**Thank you for your cooperation.**

- Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:
  - about half as long for the heavier ball as for the lighter one.
  - about half as long for the lighter ball as for the heavier one.
  - about the same for both balls.
  - considerably less for the heavier ball, but not necessarily half as long.
  - considerably less for the lighter ball, but not necessarily half as long.
- The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation:
  - both balls hit the floor at approximately the same horizontal distance from the base of the table.
  - the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
  - the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
  - the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
  - the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.
- A stone dropped from the roof of a single story building to the surface of the earth:
  - reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
  - speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.
  - speeds up because of an almost constant force of gravity acting upon it.
  - falls because of the natural tendency of all objects to rest on the surface of the earth.
  - falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.
- A large truck collides head-on with a small compact car. During the collision:
  - the truck exerts a greater amount of force on the car than the car exerts on the truck.
  - the car exerts a greater amount of force on the truck than the truck exerts on the car.
  - neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
  - the truck exerts a force on the car but the car does not exert a force on the truck.
  - the truck exerts the same amount of force on the car as the car exerts on the truck.

**USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (5 and 6).**

The accompanying figure shows a frictionless channel in the shape of a segment of a circle with center at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r."

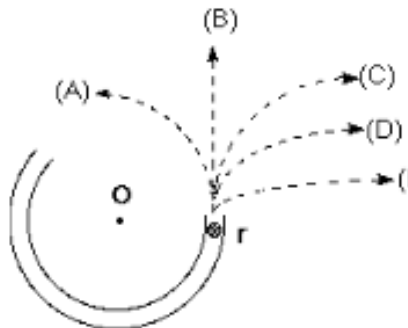


5. Consider the following distinct forces:
1. A downward force of gravity.
  2. A force exerted by the channel pointing from q to O.
  3. A force in the direction of motion.
  4. A force pointing from O to q.

Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?

- (A) 1 only.  
 (B) 1 and 2.  
 (C) 1 and 3.  
 (D) 1, 2, and 3.  
 (E) 1, 3, and 4.

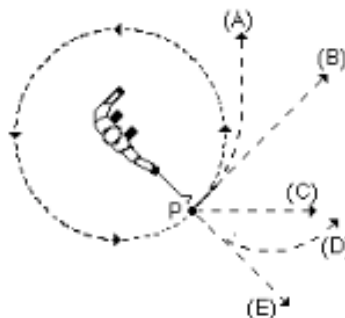
6. Which path in the figure at right would the ball most closely follow after it exits the channel at "r" and moves across the frictionless table top?



7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure.

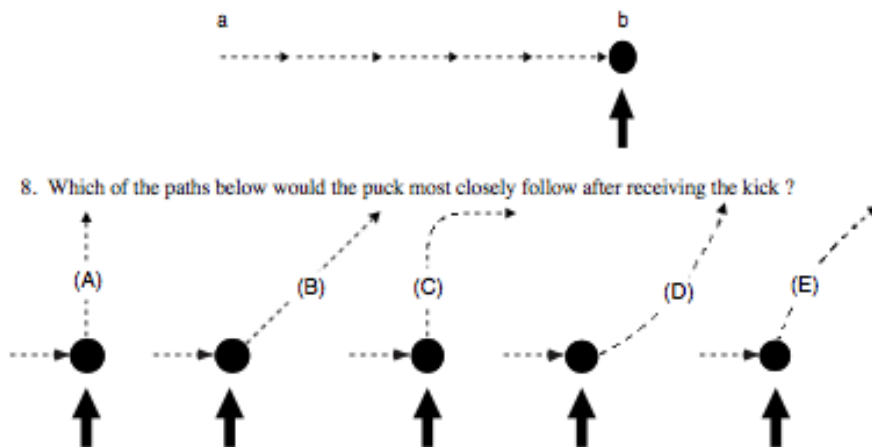
At the point P indicated in the figure, the string suddenly breaks near the ball.

If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?



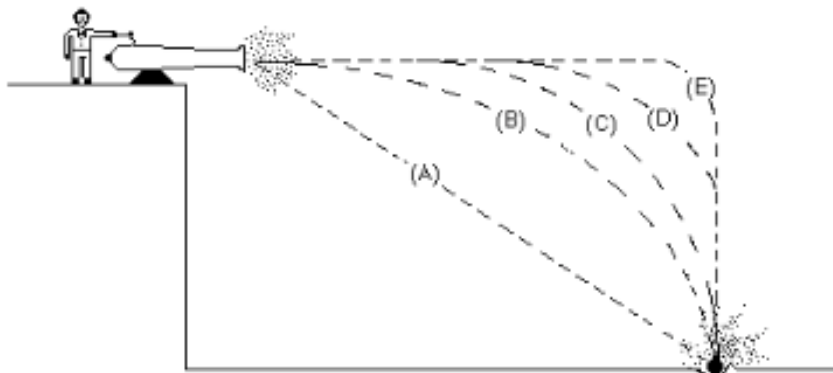
**USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 through 11).**

The figure depicts a hockey puck sliding with constant speed  $v_0$  in a straight line from point "a" to point "b" on a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down on the puck. When the puck reaches point "b," it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point "b," then the kick would have set the puck in horizontal motion with a speed  $v_k$  in the direction of the kick.



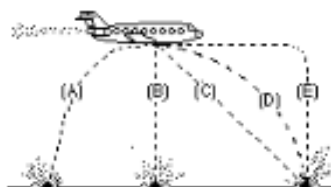
8. Which of the paths below would the puck most closely follow after receiving the kick ?
9. The speed of the puck just after it receives the kick is:
- equal to the speed " $v_0$ " it had before it received the kick.
  - equal to the speed " $v_k$ " resulting from the kick and independent of the speed " $v_0$ ".
  - equal to the arithmetic sum of the speeds " $v_0$ " and " $v_k$ ".
  - smaller than either of the speeds " $v_0$ " or " $v_k$ ".
  - greater than either of the speeds " $v_0$ " or " $v_k$ ", but less than the arithmetic sum of these two speeds.
10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick:
- is constant.
  - continuously increases.
  - continuously decreases.
  - increases for a while and decreases thereafter.
  - is constant for a while and decreases thereafter.
11. Along the frictionless path you have chosen in question 8, the main force(s) acting on the puck after receiving the kick is (are):
- a downward force of gravity.
  - a downward force of gravity, and a horizontal force in the direction of motion.
  - a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
  - a downward force of gravity and an upward force exerted by the surface.
  - none. (No forces act on the puck.)

12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?



13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):
- (A) a downward force of gravity along with a steadily decreasing upward force.
  - (B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.
  - (C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.
  - (D) an almost constant downward force of gravity only.
  - (E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.

14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?



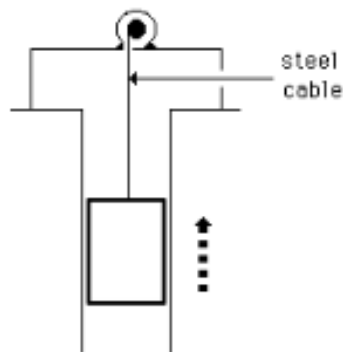
**USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).**

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.



15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
  - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
  - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
  - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
  - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.
16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
- (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
  - (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
  - (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
  - (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
  - (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.
-

17. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:
- the upward force by the cable is greater than the downward force of gravity.
  - the upward force by the cable is equal to the downward force of gravity.
  - the upward force by the cable is smaller than the downward force of gravity.
  - the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
  - none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).



Elevator going up  
at constant speed

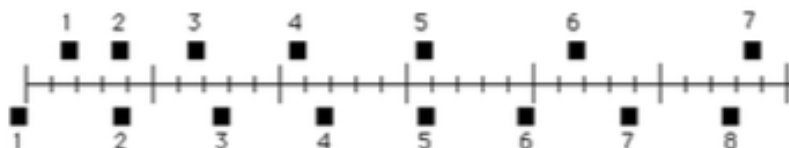
18. The figure below shows a boy swinging on a rope, starting at a point higher than A. Consider the following distinct forces:
- A downward force of gravity.
  - A force exerted by the rope pointing from A to O.
  - A force in the direction of the boy's motion.
  - A force pointing from O to A.

Which of the above forces is (are) acting on the boy when he is at position A?

- 1 only.
- 1 and 2.
- 1 and 3.
- 1, 2, and 3.
- 1, 3, and 4.

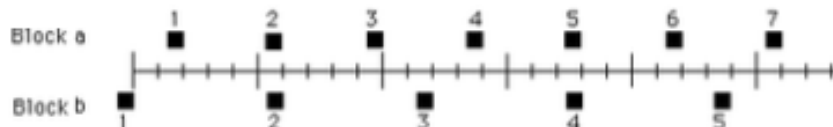


19. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



Do the blocks ever have the same speed?

- (A) No.  
 (B) Yes, at instant 2.  
 (C) Yes, at instant 5.  
 (D) Yes, at instants 2 and 5.  
 (E) Yes, at some time during the interval 3 to 4.
20. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.

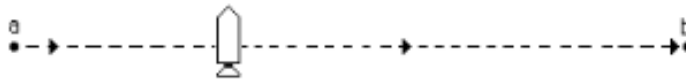


The accelerations of the blocks are related as follows:

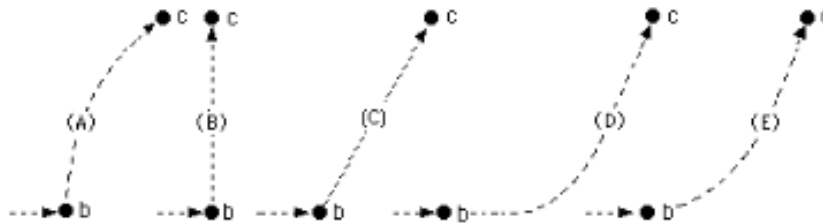
- (A) The acceleration of "a" is greater than the acceleration of "b".  
 (B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.  
 (C) The acceleration of "b" is greater than the acceleration of "a".  
 (D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.  
 (E) Not enough information is given to answer the question.
-

**USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (21 through 24).**

A rocket drifts sideways in outer space from point "a" to point "b" as shown below. The rocket is subject to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to the line "ab". The constant thrust is maintained until the rocket reaches a point "c" in space.



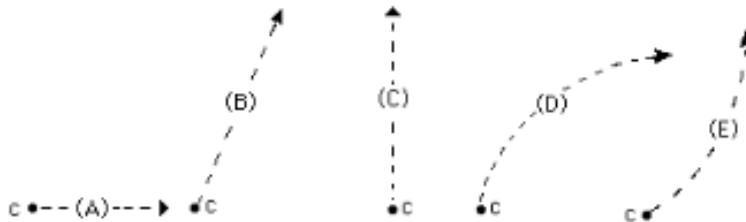
21. Which of the paths below best represents the path of the rocket between points "b" and "c"?



22. As the rocket moves from position "b" to position "c" its speed is:

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

23. At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?



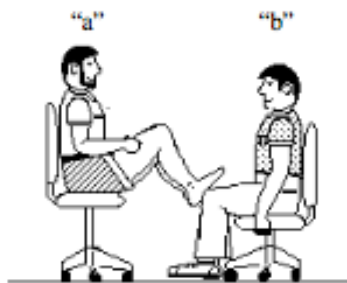
24. Beyond position "c" the speed of the rocket is:

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed " $v_0$ ".
- The constant horizontal force applied by the woman:
- (A) has the same magnitude as the weight of the box.
  - (B) is greater than the weight of the box.
  - (C) has the same magnitude as the total force which resists the motion of the box.
  - (D) is greater than the total force which resists the motion of the box.
  - (E) is greater than either the weight of the box or the total force which resists its motion.
26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
- (A) with a constant speed that is double the speed " $v_0$ " in the previous question.
  - (B) with a constant speed that is greater than the speed " $v_0$ " in the previous question, but not necessarily twice as great.
  - (C) for a while with a speed that is constant and greater than the speed " $v_0$ " in the previous question, then with a speed that increases thereafter.
  - (D) for a while with an increasing speed, then with a constant speed thereafter.
  - (E) with a continuously increasing speed.
27. If the woman in question 25 suddenly stops applying a horizontal force to the box, then the box will:
- (A) immediately come to a stop.
  - (B) continue moving at a constant speed for a while and then slow to a stop.
  - (C) immediately start slowing to a stop.
  - (D) continue at a constant speed.
  - (E) increase its speed for a while and then start slowing to a stop.

28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other.

Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.



During the push and while the students are still touching one another:

- (A) neither student exerts a force on the other.  
 (B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".  
 (C) each student exerts a force on the other, but "b" exerts the larger force.  
 (D) each student exerts a force on the other, but "a" exerts the larger force.  
 (E) each student exerts the same amount of force on the other.
29. An empty office chair is at rest on a floor. Consider the following forces:
1. A downward force of gravity.
  2. An upward force exerted by the floor.
  3. A net downward force exerted by the air.
- Which of the forces is (are) acting on the office chair?
- (A) 1 only.  
 (B) 1 and 2.  
 (C) 2 and 3.  
 (D) 1, 2, and 3.  
 (E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)
30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court. Consider the following forces:
1. A downward force of gravity.
  2. A force by the "hit".
  3. A force exerted by the air.
- Which of the above forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?
- (A) 1 only.  
 (B) 1 and 2.  
 (C) 1 and 3.  
 (D) 2 and 3.  
 (E) 1, 2, and 3.

APPENDIX D

TEST OF SCIENCE RELATED ATTITUDES (TOSRA)

TORSA Test of Science Related Attitudes

This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted. Select the answer that best represents your opinion. Questions in bold will be left off the survey

**1. Money spent on science is well worth spending.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**2. Scientists usually like to go to their laboratories when they have a day off.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

3. I would prefer to find out why something happens by doing an experiment than by being told.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

4. I enjoy reading about things which disagree with my previous ideas.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

5. Science lessons are fun.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

6. I would like to belong to a science club.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

7. I would dislike being a scientist after I leave school.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**8. Science is man's worst enemy.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**9. Scientists are about as fit and healthy as other people.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

10. Doing experiments is not as good as finding out information from teachers.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

11. I dislike repeating experiments to check that I get the same results.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

12. I dislike science lessons.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

13. I get bored when watching science programs on TV at home.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

14. When I leave school, I would like to work with people who make discoveries in science.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**15. Public money spent on science in the last few years has been used wisely.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**16. Scientists do not have enough time to spend with their families.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

17. I would prefer to do experiments than to read about them.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

18. I am curious about the world in which we live.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

19. School should have more science lessons each week.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

20. I would like to be given a science book or a piece of scientific equipment as a present.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

21. I would dislike a job in a science laboratory after I leave school.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**22. Scientific discoveries are doing more harm than good.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**23. Scientists like sport as much as other people do.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

24. I would rather agree with other people than do an experiment to find out for myself.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

25. Finding out about new things is unimportant.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

26. Science lessons bore me.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

27. I dislike reading books about science during my holidays.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

28. Working in a science laboratory would be an interesting way to earn a living.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**29. The government should spend more money on scientific research.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**30. Scientists are less friendly than other people.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

31. I would prefer to do my own experiments than to find out information from a teacher.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

32. I like to listen to people whose opinions are different from mine.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

33. Science is one of the most interesting school subjects.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

34. I would like to do science experiments at home.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

35. A career in science would be dull and boring.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**36. Too many laboratories are being built at the expense of the rest of education.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**37. Scientists can have a normal family life.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

38. I would rather find out about things by asking an expert than by doing an experiment.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

39. I find it boring to hear about new ideas.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

40. Science lessons are a waste of time.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

41. Talking to friends about science after school would be boring.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

42. I would like to teach science when I leave school.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**43. Science helps to make life better.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**44. Scientists do not care about their working conditions.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

45. I would rather solve a problem by doing an experiment than be told the answer.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

46. In science experiments, I like to use new methods which I have not used before.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

47. I really enjoy going to science lessons.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

48. I would enjoy having a job in a science laboratory during my school holidays.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

49. A job as a scientist would be boring.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**50. This country is spending too much money on science.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**51. Scientists are just as interested in art and music as other people are.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

52. It is better to ask the teacher the answer than to find it out by doing experiments.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

53. I am unwilling to change my ideas when evidence shows that the ideas are poor.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

54. The material covered in science lessons is uninteresting.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

55. Listening to talk about science on the radio would be boring.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

56. A job as a scientist would be interesting.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**57. Science can help to make the world a better place in the future.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**58. Few scientists are happily married.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

59. I would prefer to do an experiment on a topic than to read about it in science magazines.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

60. In science experiments. I report unexpected results as well as expected one.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

61. I look forward to science lessons.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

62. I would enjoy visiting a science museum at the weekend.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

63. I would dislike becoming a scientist because it needs too much education.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

**64. Money used on scientific projects is wasted.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

**65. If you met a scientist, he would probably look like anyone else you might meet.**

**Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree**

66. It is better to be told scientific facts than to find them out from experiments.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

67. I dislike listening to other people's opinions.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

68. I would enjoy school more if there were no science lessons.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

69. I dislike reading newspaper articles about science.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

70. I would like to be a scientist when I leave school.

Strongly Disagree    Disagree    Uncertain    Agree    Strongly Agree

APPENDIX E  
WALLER'S INTERVIEW QUESTIONS

## Waller's Interview Questions

### Pre Unit

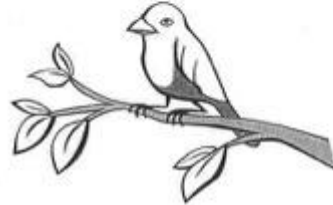
1. What do you look forward to learning in the upcoming unit?
2. Based on the learning targets posted for the upcoming unit, do you feel like there are any concepts in the upcoming unit that you do not understand correctly?
3. What strategies do your teachers use that you feel are most effective in helping you to understand new material? Is there anything else you want me to know going into this unit.

### Post Unit

4. What did you enjoy most about this unit?
5. Do you feel like there are any concepts that you do not understand correctly?
6. Do you feel that the misconception probes helped you identify the ideas you were understanding incorrectly?
7. Can you explain why when you drop a bouncy ball and a marble (that is the same size but heavier) they hit the ground at the same time?
8. How do you feel about using the conceptual change model in class, do you feel that it helps you learn?

APPENDIX F  
MISCONCEPTION PROBES

# Experiencing Gravity



What kinds of objects experience gravitational force?  
Put an X in the correct boxes.

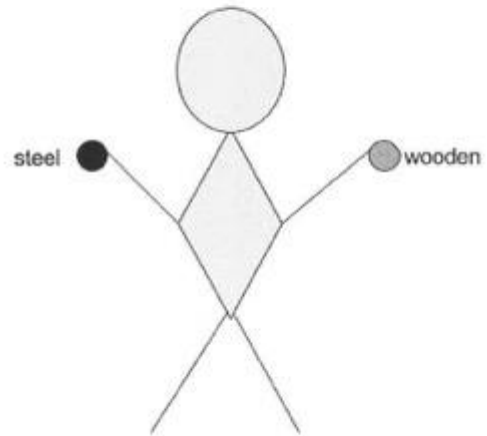
Object	Yes	No	It depends. (Describe the condition it depends on.)
Ball thrown up in the air			
Rock falling off a cliff			
Rock resting on the ground			
Flying bird			
Bird perched on a branch			
Astronaut on the Moon			
Astronaut in orbit in the Space Shuttle			
Star in outer space			
Fish swimming in water			
Person floating in water			
Stone sinking in water			
Speck of dust			
Speeding car			
Helium balloon floating up in the air			
An object buried in the ground			

What rule or reasoning did you use to decide if an object experiences gravitational force?

## WHICH WILL HIT THE GROUND FIRST

Mrs. Waller is holding one ball in each hand. One is a heavy steel ball the other is a light wooden ball. They are both about the same size. If she drops both of the balls at the same time which will hit the ground first.

- A) The steel ball
- B) The wooden ball
- C) They will both hit the ground at the same time.



Why did you pick the answer you picked, give reasoning based on evidence if possible?

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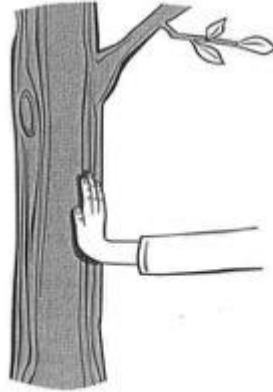
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## Equal and Opposite

Newton's third law of motion is often stated as, "For every action there is an equal and opposite reaction." Place an X next to each of the statements where the described forces are examples of Newton's third law:

- A** You push on a tree with your hand and the tree pushes back on your hand.
- B** A small car tows a large truck and they move at constant speed. The truck pulls back on the car and the car pulls on the truck.
- C** A small car tows a large truck and they speed up. The truck pulls back on the car and the car pulls on the truck.
- D** The Earth pulls down on you (your weight) and the floor pushes up on you.
- E** Billy pushes Johnny and causes Johnny to fall down. Johnny exerts a force on Billy and Billy exerts a force on Johnny.
- F** You pull on the door of the classroom and the door opens. Your hand exerts a force on the door and the door exerts a force on your hand.
- G** A horse is pulling on a cart and the cart is speeding up. The horse exerts a force on the cart and the cart exerts a force on the horse.
- H** You hold a book against the wall. You apply a force to the book and the wall applies a force on the book.



Explain your thinking. Describe the rule or reason you used to decide whether a statement fits Newton's third law.

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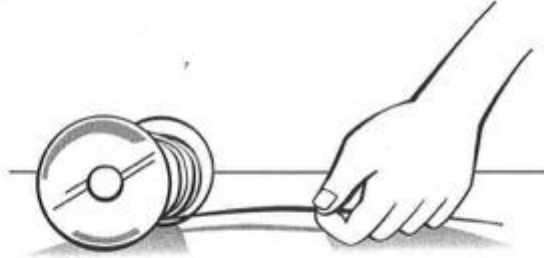


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## Pulling on a Spool



Newton's second law of motion states that the net force acting on an object will cause the object to accelerate in the direction of the net force.

Suriya wants to use wooden spools to make a toy. She first has to figure out how to make a spool roll. She wraps a string around a spool as shown. When Suriya pulls the string slowly to the right, what do you think will happen to the spool? Circle the answer that you think is the best.

- A** The spool will accelerate to the right in the direction of the pull.
- B** The spool will accelerate to the left, opposite to the direction of the pull.
- C** The spool will accelerate neither to the right or left—it will move straight ahead.

Explain the reason for your answer.

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## Lifting Buckets

Seth needs to lift a heavy bucket of sand to the second-floor balcony of his house. He ties a rope to the bucket and then stands on the balcony and pulls the bucket straight up. Once the bucket starts moving, how should Seth pull it to get it to move up at a constant speed? Circle your answer.



- A** With a force equal to the weight of the bucket and rope
- B** With a force greater than the weight of the bucket and rope
- C** With a force less than the weight of the bucket and rope

Describe your thinking about forces. Provide an explanation to support your ideas.

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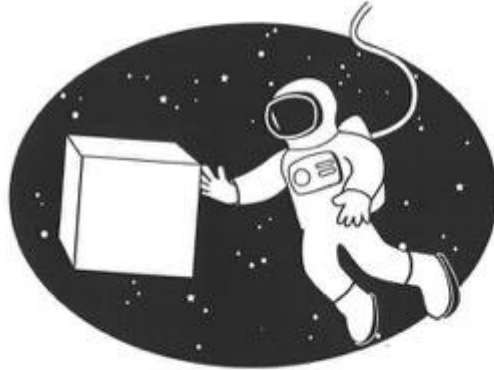
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## Outer Space Push

A box is lying on the table. You give the box a quick shove and notice that the box slides on the table for a short time and then comes to a stop. You then do the same thing on a smooth floor. With the same push from your hand, the box slides for a longer time, but then eventually comes to a stop. You wonder what would happen if you could push the box in outer space, away from any other planets or atmosphere. If



you could give the box the same push, what do you think would happen? Circle the answer that best matches your thinking.

- A** The box will move forever because nothing is slowing the box down.
- B** The box will slow down because the push that you gave it will eventually wear out.
- C** The box will slow down because it will eventually lose all its energy.

Explain your thinking. Describe the reasoning you used for your answer.

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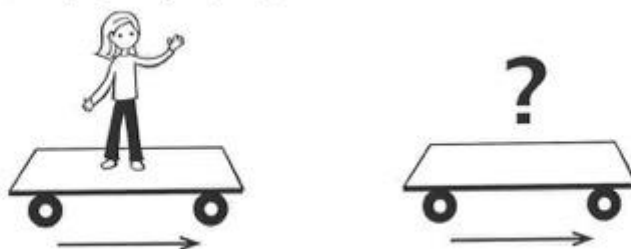
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## Riding in the Parade

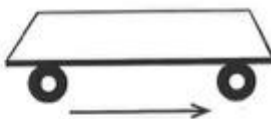
Cindy is very excited—she has been asked to ride in a parade! During the parade, she stands in the middle of the float and waves to the crowd while the float is moving down the street at a constant speed. While she is waving, she sees her friend standing on the sidewalk. She jumps straight up as high as she can so that her friend will see her.



When Cindy lands back on the float, where will she land?

- A** She will land in the same place on the float from where she jumped.
- B** She will land closer to the front of the float than where she was before she jumped.
- C** She will land closer to the back of the float than where she was before she jumped.

Draw where Cindy will land on the float (below).



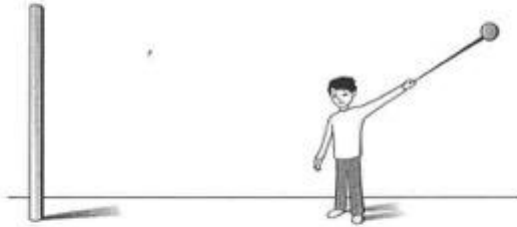
Explain your thinking. Describe the reasoning you used to make your prediction.

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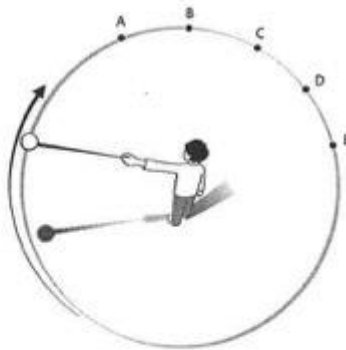


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## Ball on a String



Philippe is playing a game at the county fair. He is trying to hit a target—a long pole—by twirling a ball on a string. The ball is making a circular motion over Philippe's head (see the diagram below). The arrow shows the direction the ball is twirling in. When do you think that Philippe should let go of the string in order to hit the target? Circle your prediction (A, B, C, D, or E) on the diagram below.



Explain your thinking. On the diagram, draw the ball's path after it leaves the point marked by the letter that you circled.

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APPENDIX G  
CONCEPTUAL CHANGE MODEL ACTIVITIES

**NEWTON'S FIRST LAW LAB**

Name \_\_\_\_\_

**Purpose:**

What is the relationship between mass and inertia? What does Newton's First Law say about inertia? How do unbalanced forces and balanced forces affect an object's motion?

**Read the directions for each station, conduct the experiment, and then complete your questions before moving to the next station.**

**Station 1: Swirling Washer**

Place washer and string completely flat on the floor. Hold the string by the end and spin the washer around your hand, while it is touching the floor. Let go of the string. Write your observations.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Explain how this demonstrates Newton's First Law. \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**Station 2: Plastic Hoop Trick**

Balance a plastic hoop on the graduated cylinder and place the chalk on the top of the hoop. Your task is to use one hand to quickly remove the hoop so that the chalk drops into the graduated cylinder.

After you have mastered the task, explain what you did to master the task. \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Explain how this demonstrates Newton's First Law. \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**Station 4: Crash Test Dummy**

Place the dented ping pong ball on cart and put cart at top of the ramp to collide with the testing divider. Make observations about the changes in motion of the car and the forces acting on the ball.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Use the rubber band to attach the ball to the cart (like a seat belt) and repeat the collision. Make the same observations about the changes in motion of the ball.

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Explain how this demonstrates Newton's First Law. \_\_\_\_\_

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**Station 5: Tablecloth Trick**

Place only the aluminum pan on top of the mini-table cloth (handkerchief). Quickly remove the table cloth out from under the pan so it stays on the table. Second, put the larger massed item on top of the aluminum pan. Quickly remove the table cloth from under the pan and massed item so they stay on the table.

Which test made it easier to pull the table cloth out? Why did it work better?

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Explain how this demonstrates Newton's First Law. \_\_\_\_\_

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**Station 7: Index Card and Coin**

Place index card on top of the clothespin on the table. Place the washer on the card over the clothespin. With the other hand, determine a method of removing the card quickly so the coin remains on the clothespin. Describe your method and why it works.

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Conduct the same test with a dime. Which test was easier? Explain why. \_\_\_\_\_



Explain how this demonstrates Newton's First Law. \_\_\_\_\_

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**Station 8: Road Trippin' (conceptual lab station)**

A boy stands in the center aisle of a bus moving down the highway at 55 mph. If the boy tosses a ball straight up toward the roof of the bus it falls back into his hands. Why?

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If someone was watching the boy doing this from a stationary position outside of the bus, what would the ball have appeared to do? \_\_\_\_\_

\_\_\_\_\_

Explain how this demonstrates Newton's First Law. \_\_\_\_\_

**Station 9: Gyroscope**

Hold the bottom of the Gyroscope with your fingers. Use your other hand to spin the inside of the Gyroscope. Let it spin until it stops.

Why did the Gyroscope spin for so long? \_\_\_\_\_

\_\_\_\_\_

\*\*How is the Gyroscope different from the spinning a top? \_\_\_\_\_

\_\_\_\_\_

Explain how this demonstrates Newton's First Law. \_\_\_\_\_

**Station 12: The Hair Dryer**

You will use four different spheres to conduct this test (**tennis ball, ping pong ball, golf ball, weighted metal ball**). One partner will release the ping pong ball at the top of the ramp. The other partner will place the hair drier next to the path of the ball near the bottom of the ramp (perpendicular to path of the spheres), attempting to make the ball change its path. Repeat test for the other three spheres. *-use balance to find the masses!*

Complete the table below, listing the spheres from **smallest** mass to **largest** mass.

Sphere	Did it deflect from path?	Was it a large or small deflection?
--------	---------------------------	-------------------------------------

Use Newton's First Law to explain why **each** of the spheres moved the way that they did.

**Station 13: David vs. Goliath Sling Shot**

Using the "swirling method," swing the plastic ball around and hit the target on the front board. Explain how you know when to release the string.

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What happens when you release the string at the wrong time? \_\_\_\_\_

Why does this happen? \_\_\_\_\_

Explain how this demonstrates Newton's First Law. \_\_\_\_\_

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**Summary:**

Based on what you have seen in this lab, answer the experimental purpose questions for this lab.

What is the relationship between mass and inertia? \_\_\_\_\_

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What does Newton's First Law say about inertia? \_\_\_\_\_

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How do unbalanced forces and balanced forces affect an object's motion?

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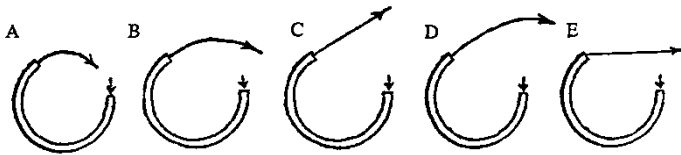
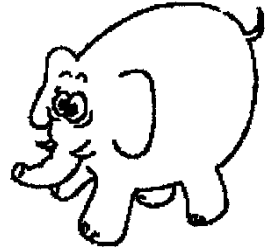
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## CONCEPTUAL QUESTIONS

### NEWTON'S FIRST LAW

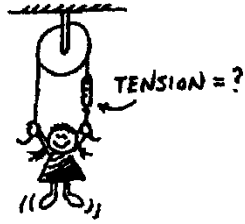
1. If you were in a spaceship and fired a cannonball into space, how much force would have to be exerted on the ball to keep it moving once it has left the spaceship?
2. Many automobile passengers have suffered neck injuries when struck by cars from behind. How does Newton's law of inertia apply here?

- How do headrests help to guard against this type of injury?
3. Suppose you place a ball in the middle of a wagon, and then accelerate the wagon forward. Describe the motion of the ball relative to the ground.
    - Describe its motion relative to the wagon.
  4. If an elephant were chasing you, its enormous mass would be most threatening. But if you zigzagged, its mass would be to your advantage. Why?
  5. Two closed containers look the same, but one is packed with lead and the other with a few feathers. How could you determine which has more mass if you and the containers were orbiting in a weightless condition in outer space?
  6. A metal ball is put into the end of the tube indicated by the arrow. The ball is then shot out of the other end of the tube at high speed. Pick the path the ball will follow after it exits the tube. Note – you are looking down on these tubes, they are not vertical.



7. How much support force does a table exert on a book that weighs 15 N when the book is placed on the table?
  - What if a hand pushes down on the book with a force of 20 N?
  - What if a rope lifts up on the book with a force of 10 N? (The hand is no longer there.)
8. When a 100 N bag of nails hangs motionless from a single vertical strand of rope, how many newtons of tension are exerted in the strand?
  - What if the bag is supported by four vertical strands?

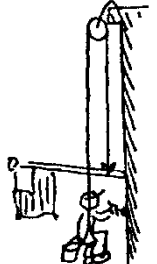
9. The little girl in the diagram at the right hangs at rest from the ends of the rope. How does the reading on the scale compare to her weight?
10. If the force of friction acting on a sliding crate is 100 N, how much force must be applied to maintain a constant velocity?
- What will be the net force acting on the crate?
  - What will be the acceleration?
11. How much does an astronaut weigh out in space, far from any planets?
12. If suddenly the force of gravity of the sun stopped acting on the planets, in what kind of path would the planets move?



## NEWTON'S SECOND LAW

1. If the forces exerted on a 2-kg object are 50 N east and 30 N west, what is object's acceleration?
2. Suppose a cart is being pushed by a certain net force. If the net force is doubled, by how much does the acceleration change?
3. Suppose a cart is being moved by a certain net force. If a box is dumped into the cart, so its mass is doubled, by how much does the acceleration change?
4. If a loaded truck can accelerate at four  $\text{m/s}^2$  and loses its load so it is only half as massive, what acceleration can it attain for the same driving force?
5. A rocket fired from its launching pad not only picks up speed, but also has a significant increase in its acceleration as firing continues. Why is this so?

6. Harry the painter swings year after year from his boson's chair. His weight is 500 N and rope unknown to him, has a breaking point of 300 N. Why doesn't the rope break when he is supported as shown in the first figure to the right?



- One day Harry is painting near a flagpole, and for a change, he ties the free end of the rope to the flagpole instead of to his chair. What happens to Harry?

7. The force of gravity is twice as great on a 2-kg rock as on a 1-kg rock. Why then does the 2-kg rock not fall with twice the acceleration?



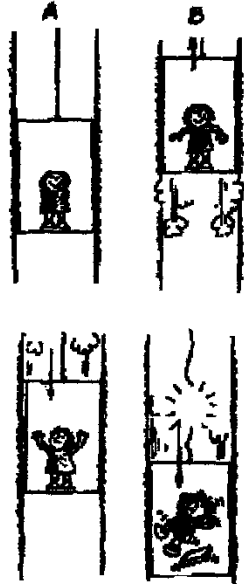
8. What is the net force acting on a 10 kg freely falling object?

$$\frac{F}{m} = \frac{F}{m}$$

- What is the net force when it encounters 15 N of air resistance?
  - How much air resistance does it experience when it falls at terminal velocity?
9. If you pulled a low but heavy crate with a rope and greased the bottom to reduce friction, would it help more to use a short rope or a long rope?

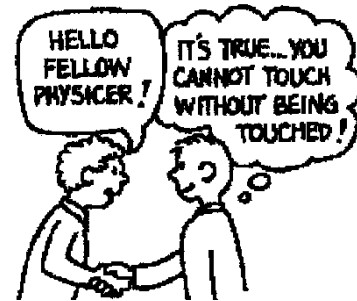
10. An elevator (mass = 1000 kg) is supported by a single cable.

- a) When the elevator is at rest, what is the tension in the cable?
- b) The elevator starts to move upwards at  $1\text{ m/s/s}$ . Is the scale reading more, less, or the same?
- c) When the elevator is ascending upward at a constant speed, is the tension more, less, or the same as (a)?
- d) The elevator begins to slow as it reaches the proper floor. Is the tension more, less, or the same as (a)?
- e) The elevator now starts to descend at an increasing speed. Is the tension more, less, or the same as (a)?
- f) If the cable snapped and the elevator fell freely, what would be the tension?



## NEWTON'S THIRD LAW

1. When a hammer exerts a force on a nail, how does the amount of force compare to that of the nail on the hammer?
2. Why does a cannon recoil when it fires a cannonball?
3. When you jump up, does the world recoil downward? Explain.

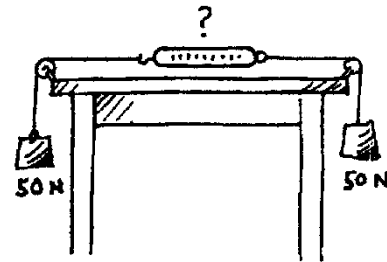


4. Why is it easier to walk on a carpeted floor than on a smooth, polished floor?

5. When a rifle is fired, how does the size of the force of the rifle on the bullet compare to the force of the bullet on the rifle?
  - How do the accelerations of the rifle and bullet compare?



6. If a bicycle and a massive truck have a head-on collision, upon which vehicle is the impact force greater?
  - Which vehicle undergoes the greater change in acceleration?



7. A pair of 50 N weights are attached to a spring scale as shown in the diagram. Does the scale read 0, 50, or 100 N?

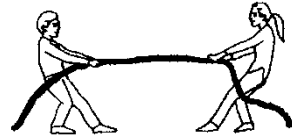
8. The strongman will push the two initially stationary freight cars of equal mass apart before he himself drops to the ground. Is it possible for him to set either of the cars in greater motion than the other? Explain.





9. Suppose two carts, one twice as massive as the other, fly apart when the compressed spring that joins them is released. Afterwards, how do their speeds compare?

10. Two people of equal mass attempt a tug-of-war with a 12-meter rope while standing on frictionless ice. When they pull on the rope, they each slide toward each other. How far does each person slide before they meet?



11. Suppose in the preceding example that one person has twice the mass of the other. How far does each person slide before they meet?

12. A horse pulls a wagon with some force, causing it to accelerate. Newton's third law says that the wagon exerts an equal and opposite reaction force on the horse. How can the wagon move?



## Will an elephant fall faster than a mouse?

Problem

Does Mass affect the rate of fall?

Hypothesis:

Procedure

1. Hold the wood block the sponge and the paper. Rank them by weight.

Which is heaviest, which is lightest?

2. Hold the block and the sponge horizontally at arm's length, so that

the flat edge is down.

3. Release the objects and observe if they land at the same time or if one

hits the ground before the other.

4. Repeat steps 2 and 3 for the different object pairs

Observations	Comparing fall rates		
Object	Trial 1	Trial 2	Trial 3
Example Tennis ball w/sand vs Tennis ball w/out sand	hit the ground at the same time	Hit the ground at the same time	Hit the ground at the same time
sponge vs wood			
sponge vs paper			
sponge vs			

crumpled paper			
Wood vs crumpled paper			
Wood vs Paper			
Paper vs crumpled paper			

**Analysis and Conclusions****Answer the questions using complete sentences.**

1. Galileo stated that 2 bodies with different masses fall at the same rate. Do your observations verify his hypothesis? Explain your answer.
2. Did crumpling the paper have any effect on its falling rate? Explain why or why not.
3. Now answer this question: Would an elephant fall faster than a mouse? Explain your answer.

## Understanding Newton's Second Law of Motion

Describe Newton's Second Law of Motion in your own words.

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What is Newton's Second Law of Motion also known as?

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Define the terms listed below. Be sure to write the definitions in your own words.

Acceleration -

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Velocity -

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Initial Velocity -

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Force -

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Newtons -

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Conduct a simple experiment with your K'NEX Rubber Band Powered Dragster.

**Step 1:** Attach the rubber band to the rear axle of your racer and turn the axle two full rotations.

**Step 2:** Place your racer on the floor and measure the distance that the vehicle travels. Record the distance.

**Step 3:** Add a 100g mass to the mass holder on the vehicle, and repeat the previous two steps.

**Step 4:** Which vehicle traveled the greatest distance?

In the space provided below, describe how Newton's second law relates to the results you found.

Distance traveled with no added mass. \_\_\_\_\_meters


Distance traveled with 100g of added mass. \_\_\_\_\_meters


## Vehicle Performance Evaluations

### Directions:

Test your K'NEX Rubber Band Powered Dragster as you alter the independent variables (number of rubber bands, axle rotations, and mass) as directed. DO NOT wind your vehicle's rubber band in excess of the specified rotations as breakage and unsafe conditions can occur.

For each of the four activities below you will collect and record the following data in the charts provided:

- The mass of the vehicle.
- The distance the vehicle travels.
- The time it takes to travel that distance.

Once you have this information, calculate the velocity (final) and acceleration of the vehicle using the formulas below.

<b>Velocity:</b>	
Velocity <sub>Final</sub> (m/sec) =	$\frac{\text{Distance (m)}}{\text{Time (sec)}}$

<b>Acceleration:</b>	
Acceleration (m/sec/sec) =	$\frac{\text{Velocity}_{\text{Final}} \text{ (m/s)} - \text{Velocity}_{\text{Initial}} \text{ (m/s)}}{\text{Time}_{\text{Final}} \text{ (sec)} - \text{Time}_{\text{Initial}} \text{ (sec)}}$

Given that the car is not moving at the start line, the Initial Velocity and the Initial Time are both zero (0). By placing two zeros in the formula above for those values, the formula is simplified to:

Acceleration (m/sec/sec) =	$\frac{\text{Velocity}_{\text{Final}} \text{ (m/s)}}{\text{Time}_{\text{Final}} \text{ (sec)}}$
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### Single Rubber Band & Axle Rotation Tests

- Use a fresh, un-stretched rubber band for these two activities.
- Find the mass of your dragster and enter the mass in the data table.
- Place a masking tape starting line on the floor. Wind the rubber band the specified number of rotations, and then place your dragster at the starting line.
- Let go and time the dragster and measure the distance it travels.
- Record your results in the data table.
- Compute the velocity and acceleration for each trial.



Vehicle Mass: _____ kg				
# of Rotations	Distance (m)	Time <sub>Final</sub> (Seconds)	Velocity <sub>Final</sub> (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				

Add a 100g mass to your K'NEX Dragster and repeat the previous activity. Remember to replace your rubber band. Record your results below.

Vehicle Mass: _____ kg				
# of Rotations	Distance (m)	Time Final (Seconds)	Velocity Final (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				

Did the vehicle perform differently with the added mass? Explain why.


### Paired Rubber Bands & Axle Rotation Tests

- Remove the rubber band from your dragster and replace it with two fresh, un-stretched rubber bands.
- Follow the same directions as you did for the previous two activities.
- Record your data in the tables below.

Vehicle Mass: _____ kg				
# of Rotations	Distance (m)	Time <sub>Final</sub> (Seconds)	Velocity <sub>Final</sub> (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				

Add a 100g mass to your dragster and repeat the activity. Remember to replace your rubber bands.

Vehicle Mass: _____ kg				
# of Rotations	Distance (m)	Time Final (Seconds)	Velocity Final (m/sec)	Acceleration (m/sec/sec)
1				
2				
3				
4				
5				

Did the dragster perform differently with an additional rubber band? Explain why.


Do you think the addition of a third rubber band would result in an increase or decrease in performance? Explain why.



### Calculating & Graphing Forces

Using the data collected during the activities and the formula below, calculate the force being exerted by the rear axle to power your dragster. Remember to convert your mass measurements to kilograms before completing your computations.

$$\text{Force (N)} = \text{Mass (kg)} \times \text{Acceleration (m/sec/sec)}$$

### Single Rubber Band Force Results

- Calculate the forces for all ten of the trials that used a single rubber band in your Design Journal.
- Organize the data in a data table of your own design.
- Take a sheet of graph paper and place the number of rotations on the X-axis and the force in Newtons (N) on the Y-axis.
- Graph the points for the two sets of data on the same graph. (Use red data points for the empty dragster and blue for the trials with added mass.)
- Use a red line for the graph of the empty dragster data and a blue line for the graph of the data from the dragster with added mass.
- Draw a smooth curve through the points for each set of data using the proper color curve.
- Label and title the graph.



Compare the red and blue curves on the graph; describe how the force changed when the mass of the vehicle was increased.

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### Double Rubber Band Force Results

- Follow the same directions as the single rubber band force results for this double rubber band activity. Use green points and lines for the empty dragster data and black points and lines for the dragster with added mass to make your graph.

Review the red, blue, green and black lines on your graphs. Explain any patterns, similarities and/or differences you observe based on your understanding of Newton's Second Law of Motion?

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Can you predict your dragster's acceleration if you to increase or decrease the mass of your dragster by 50g? If so, explain how you would accomplish this. If not, why not?

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### Falling Objects Claim-Evidence-Reasoning (CER) Writing Assignment

Directions: Read the following Prompt. Then construct a scientific argument, using the Claim-Evidence-Reasoning (CER) framework, that answers the Scientific Question below. Use what you learned in class about falling objects.

Prompt: A group of students performed an experiment to investigate the acceleration of different falling objects on Earth. In the experiment, the students dropped each object from a height of 5.0 meters, and carefully measured the speed (in meters per second) and the time (in seconds), using electronic sensors. The objects included a small round ball (3-inch diameter round plastic ball) and a large rectangular block (5-inch cube shaped Styrofoam block). The Styrofoam block's weight was four times the amount of weight of the plastic ball.

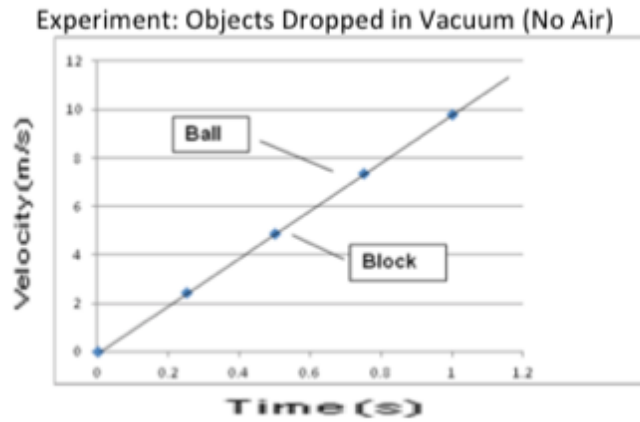
Table 1.

*Data resulting from an investigation in which objects inside a large vacuum tube were dropped after removing the air inside the tube.*

Time (s)	Speed (m/s)	
	Small ball	Large block
0	0	0
.25	2.45	2.45
.50	4.9	4.9
.75	7.35	7.35
1.00	9.8	9.8

The students created the following velocity (speed) vs. time graph of the data for the experiment. After plotting the data points, they drew the best fit line through the points, as shown below.

Experiment: Objects Dropped in Vacuum (No Air)



The students used the slope of the best fit line to determine the acceleration ( $\Delta v/\Delta t$ ) of each object. After looking at the results, one of the students remarked, “Wow, both objects had an acceleration of  $9.8 \text{ m/s}^2$ . That’s exactly the acceleration due to the force of gravity on the surface of the Earth. I wonder what the accelerations of the objects would be if they were falling through air.”

Scientific Question: Which of the two objects do you predict would have the greater acceleration when dropped in air?

Name \_\_\_\_\_ Period \_\_\_\_\_ Date \_\_\_\_\_

**Chapter 6: Newton's Third Law of Motion—  
Action and Reaction**

**Action and Reaction**

# 18 Tug-of-War

**Experiment**

**Purpose**

To investigate the tension in a string, the function of a simple pulley, and a simple "tug-of-war."

**Required Equipment/Supplies**

- |                                |                        |
|--------------------------------|------------------------|
| 5 large paper clips            | 2 low-friction pulleys |
| 2 large identical rubber bands | 2 ring stands          |
| 2 m of strong string           | spring scale           |
| 2 500-g hook masses            | measuring rule         |

**Discussion**

Suppose you push on the back of a stalled car. You are certainly aware that you are exerting a force on the car. Are you equally aware that the car is exerting a force on you? And that the magnitudes of the car's force on you and your force on the car are the same? A force cannot exist alone. Forces are always the result of interactions between two things, and they come in balanced pairs.

Now suppose you get a friend to tie a rope to the front of the car and pull on it. The rope will be pulling back on your friend with exactly the same magnitude of force that she is exerting on the rope. The other end of the rope will be pulling on the car and the car will be pulling equally back on it. There are two interaction pairs, one where your friend grasps the rope and one where the rope is attached to the car.

A rope or string is a transmitter of force. If it is not moving or it is moving but has a negligible mass, the forces at its two ends will also be equal. In this activity, you will learn about balanced pairs of interaction forces and about the way a string transmits forces.



Fig. A

**Procedure**

**Step 1:** Suspend a 500-g load from a string that is held by a spring scale as shown in Figure A.

1. What does the scale reading tell you about the tension in the string?

*Put tension on a string.*

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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*Hang weight over pulley.*

**Step 2:** Drape the string over a pulley such that both ends of the string hang vertically, as shown in Figure B. Hold the scale steady so that it supports the hanging load.

2. What does the scale read, and how does this force compare with the weight of the load?

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3. How does it compare with the tension in the string?

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*Move spring scale to different positions along vertical.*

**Step 3:** Move the spring scale first to a higher, then to a lower position, keeping the strings on each side of the pulley vertical.

4. Does the reading at the higher position change?

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5. Move the scale to a lower position. Does the reading at the lower position change? Briefly explain these results.

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Fig. B



Fig. C



Fig. D



Fig. E

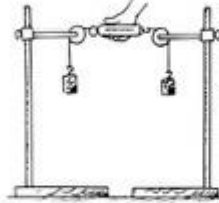


Fig. F

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Name	Period	Date
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**Step 4:** Move the spring scale to various angles to the vertical, until the scale is horizontal, as shown in Figure C.

*Move spring scale to different positions away from vertical.*

6. Does the reading on the scale ever deviate from what you measured in the previous steps? Briefly explain your result.

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**Step 5:** Remove the string from the pulley and drape it over a horizontal rod. Repeat Step 4, as shown in Figure D.

*Hang weight over rod.*

7. Do you find a difference between the results of Steps 4 and 5? Explain.

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**Step 6:** 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 E.

*Pull on both ends of string over pulley.*

8. What do the scales read?

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9. What role does friction play in the function of a pulley?

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Have mini tug-of-war with two spring scales.



**Step 7:** Have your partner hold one end of a spring scale stationary while you pull horizontally on the other end. Pull until the scale reads the same force as it did when suspending the mass. Record the following observations.

- 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 = \_\_\_\_\_

Attach string to wall and tug.



**Step 8:** Attach strings on both ends of the spring scale. Fasten one end to the wall or a steady support. Call this String A. Pull horizontally on the other string, String B, until the scale reads the same as in the previous step. Record the following observations.

- force you exert on String A = \_\_\_\_\_
- force String A exerts on scale = \_\_\_\_\_
- force the scale exerts on String B = \_\_\_\_\_
- force String B exerts on the wall = \_\_\_\_\_
- force the wall exerts on String B = \_\_\_\_\_

10. What is the essential difference between the situations in Step 7 and Step 8?

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Think and Explain

11. From a microscopic point of view, how does the spring or string transmit the force you are exerting on your partner or the wall?

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**Step 9:** Study Figure F and predict the reading on the scale when two 500-g loads are supported at each end of the strings. Then assemble the apparatus and check your prediction.

- predicted scale reading = \_\_\_\_\_
- actual scale reading = \_\_\_\_\_

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APPENDIX H  
CER FRAMEWORK

## SCIENTIFIC EXPLANATIONS

# CLAIM

Statement about the results of an investigation

- A one-sentence answer to the question you investigated.
- It answers, **what can you conclude?**
- It should not start with **yes** or **no**.
- It should describe the relationship between **dependent** and **independent** variables.

# EVIDENCE

Scientific data used to support the claim

Evidence must be:

- **Sufficient** — Use enough evidence to support the claim.
- **Appropriate** — Use data that support your claim. Leave out information that doesn't support the claim.
- **Qualitative** — (Using the senses), or **Quantitative** (numerical), or a combination of both.

# REASONING

Ties together the claim and the evidence

- Shows **how** or **why** the data count as evidence to support the claim.
- Provides the justification for why **this** evidence is important to **this** claim.
- Includes one or more **scientific principles** that are important to the claim and evidence.

**\*Remember:** Read what you've written to be sure it makes sense as a whole explanation.

APPENDIX I

CHEMICAL REACTIONS UNIT OUTLINE AND LESSONS

## Chemical Reactions Lesson Outline

<b>DAY</b>	<b>INSTRUCTIONAL OBJECTIVE</b>	<b>HOMEWORK/PRACTICE</b>
DAY 1	Students read from book and take notes	PRACTICE PAGE
DAY 2	Teacher Instruction on writing chemical equations	PRACTICE PAGE
DAY 3	Teacher Instruction on balancing chemical equations	PRACTICE PAGE
DAY 4-5	Balancing Equations lab	CONCLUSION QUESTIONS
DAY 6	Go over conclusion ?S More teacher instruction on balancing equations	PRACTICE PAGE
DAY 7	In class activity balancing equations race	PRACTICE PAGE
DAY 8	Teacher instruction on types of chemical reactions	PRACTICE PAGE
DAY 9	Types of Chemical Reactions Lab	---
DAY 10	Student worktime to finish lab Turn in for lab for grading and feedback	CONCLUSION QUESTIONS
DAY 11	Worktime to work on making corrections to the types of chemical reactions lab	--
DAY 12	Kahoot review	Study for test
DAY 13	Test	--

APPENDIX J

CHEMICAL REACTIONS UNIT MATERIALS

# Chemical Reactions

1. **Describe ways that matter can change physically and chemically and explain what a chemical reaction is.**
2. **Distinguish between endothermic and exothermic chemical reactions.**
3. **Classify reactions as synthesis, decomposition, single displacement, or double displacement.**
4. **Analyze energy changes that accompany chemical reactions, such as in heat packs, cold packs, and glow sticks.**
5. **Discuss the laws of conservation of matter and energy as they relate to chemical reactions.**
6. **Write balanced equations to represent simple chemical reactions.**

Name: \_\_\_\_\_

What is a chemical reaction?

A chemical reaction is a process in which one or more \_\_\_\_\_ are changed into another \_\_\_\_\_ .

We know a chemical reaction has occurred when we get something new and we see the following indicators

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

There are two main types of chemical reactions

\_\_\_\_\_ and \_\_\_\_\_  
Endothermic reactions are reactions where energy is \_\_\_\_\_

You can tell its endothermic because it will often get \_\_\_\_\_  
Example:

Exothermic reaction are reaction where energy is \_\_\_\_\_

You can tell is exothermic because it will often produce heat and light.  
Example:

Chemical reactions always involve a change in \_\_\_\_\_ .  
Note that while energy can \_\_\_\_\_  
be neither created nor destroyed in a chemical reaction, it can be \_\_\_\_\_ .

Chemical reactions either absorb energy or give off energy and are classified respectively as either endothermic or exothermic.

We can break down reactions into more types based on what happens to the molecules in the compounds.

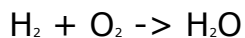
### Types of reactions

---

---

In a synthesis reaction two becomes one

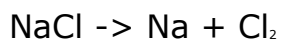
Two element or compounds combine to form one compound



---

In a decomposition reaction one becomes two or more

One substance become two or more simpler substances



---

There are two types of displacement reactions

Single and double

Single- a single element kicks out a similar element

Single- \_\_\_\_\_

Double- two compounds switch partners

Double- \_\_\_\_\_

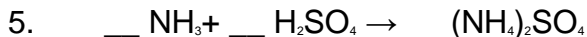
Homework: [Types of Chemical Reactions worksheet](#)

## Types of Chemical Reaction Worksheet

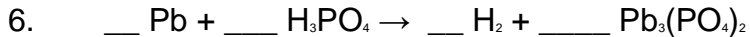
*Balance the reactions 1 to 7 and indicate which type of chemical reaction (synthesis, decomposition, single-displacement, double-displacement) is being represented:*



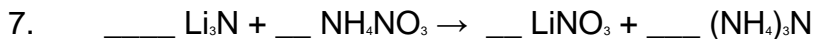
Reaction Type : \_\_\_\_\_



Reaction Type : \_\_\_\_\_



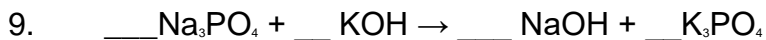
Reaction Type : \_\_\_\_\_



Reaction Type : \_\_\_\_\_



Reaction Type : \_\_\_\_\_

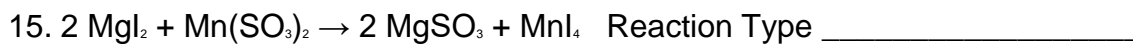


Reaction Type: \_\_\_\_\_



Reaction Type:  $\underline{\hspace{4cm}}$

*Indicate which type of chemical reaction (synthesis, decomposition, single-displacement, double-displacement) is being represented in 8 to 17.*

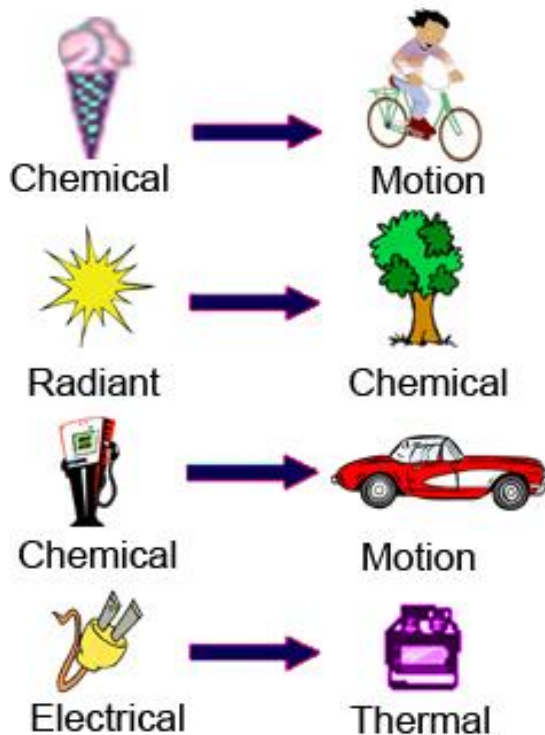


## Conservation of Matter and Energy

- In the previous section you learned about chemical reactions and about exothermic and endothermic processes.
  - Think about how atoms in the reactants change into the products as a chemical reaction proceeds.
- It is important to understand that atoms are neither created nor destroyed as chemical reactions take place.
- Atoms are only \_\_\_\_\_ . It is also important to realize that regardless of whether a reaction is exothermic or endothermic, \_\_\_\_\_ new energy is created or destroyed; it must come from somewhere, and it must go somewhere.
  - Neither \_\_\_\_\_ nor \_\_\_\_\_ ever disappears, though both can change \_\_\_\_\_ and \_\_\_\_\_ through space.

## **Chemical Reactions and Energy**

## Energy Transformations



- One of the most important concepts of energy is that it is conserved. The law of conservation of energy states:
- **Energy can be converted from one form to another but that it can be neither created nor destroyed.**
- This law tells us that the total amount of energy in the universe is \_\_\_\_\_, though it does change forms.
- The law also tells us that in a chemical reaction, all energy gains and losses must be accounted for.

## Energy Changes

- Energy changes must always accompany chemical reactions.
  - You just learned how the law of conservation of energy demands that any energy released from a chemical

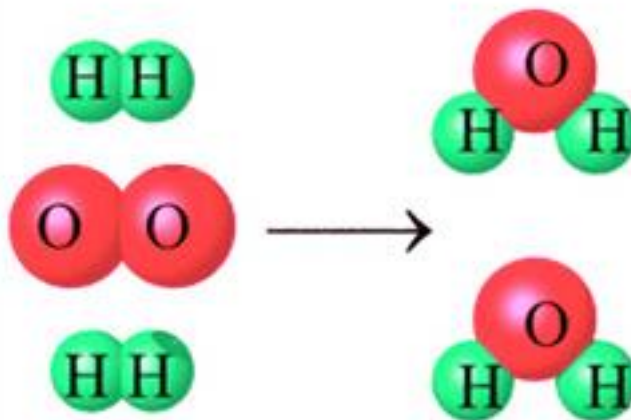
reaction be equal to the energy gained by the surroundings and vice versa.

- Chemical reactions involve changes in energy because of the chemical bonds that hold atoms together.
  - When a chemical reaction takes place, the bonds between atoms are rearranged. This involves breaking the chemical bonds in reactant molecules and forming new bonds in the product molecules. The two key points here are:
    - \_\_\_\_\_ chemical bonds requires energy and is therefore an endothermic process.
    - \_\_\_\_\_ chemical bonds gives out energy and is therefore an exothermic process.

#### Conservation of Matter

- At this point you have learned about the law of conservation of energy and how energy is conserved in chemical reactions.
- You will now learn about the law of conservation of matter.
  - Like energy, matter is always conserved in a chemical reaction.
- **The law of conservation of matter says that matter cannot be created or destroyed.**
- Therefore, in a chemical reaction, no new atoms are created and none are destroyed. They are only \_\_\_\_\_ .
- You can see this when you look at chemical reactions.
  - In a displacement reaction, for example, one or more elements in a compound switch places with another element.
- In the diagram below you see a simple reaction of two molecules of hydrogen ( $H_2$ ) reacting with a molecule of oxygen ( $O_2$ ) to form two molecules of water ( $H_2O$ ).

- Note how the atoms are only rearranged and that nothing is lost or created.



- The law of conservation of matter demands that all atoms present in the \_\_\_\_\_ of a chemical reaction must be accounted for in the \_\_\_\_\_ .
  - In other words, there must be the same number of each type of atom on the product side and on the reactant side.
- Making sure that this rule is obeyed is called \_\_\_\_\_ a chemical equation for a reaction, but first lets talk about writing an equation

### Writing Chemical Equations

- First write a sentence clarifying the reaction. Sometimes seeing the reaction on paper helps you to be able to tear apart and analyze the equation. Make sure to include all the names and

states of your products and reactants. Once you have these written out, you can start writing out your equation.

- a. For an example, we will use water. If we were to write the reaction that produces water in a sentence we would say: Hydrogen added to Oxygen yields water.

- i. Example:

2. Write down your product and reactants. Make sure that your reactants are on the left side of your equation and your products are on the right.

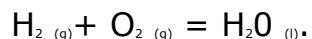
For our example it would look like this.

Hydrogen + Oxygen -----> Water

Example:

3. Insert the correct symbols to replace the words for your product and reactants, remember if you know the phases you should write those as well.

For our example it would look like this:



Example:

Homework: [Writing Chemical Equations](#)

## Chemistry: Identifying Chemical Reactions

Identify the type of each type of reaction.

**Synthesis**

**Decomposition**

**Single displacement** or **Single replacement**

**Double displacement** or **Single replacement**

Write balanced equations for each of the word equations below, then indicate which kind of reaction it is

1. Sodium bromide + Calcium hydroxide → Calcium bromide + Sodium hydroxide

Type of reaction = \_\_\_\_\_

2. Ammonia + Sulfuric Acid → Ammonium sulfate

Type of reaction = \_\_\_\_\_

4. Lead(II) + Phosphoric acid → Hydrogen gas + Lead phosphate

Type of reaction = \_\_\_\_\_

5. Lithium nitride + Ammonium nitrate → Lithium nitrate + Ammonium nitride

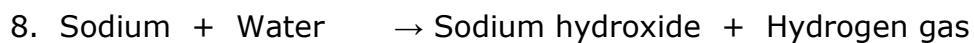
Type of reaction = \_\_\_\_\_

6. Hydrobromic acid + Aluminum hydroxide → Water + Aluminum bromide

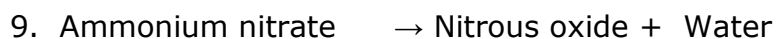
Type of reaction = \_\_\_\_\_



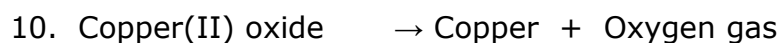
Type of reaction = \_\_\_\_\_



Type of reaction = \_\_\_\_\_



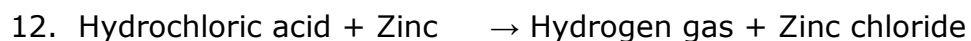
Type of reaction = \_\_\_\_\_



Type of reaction = \_\_\_\_\_



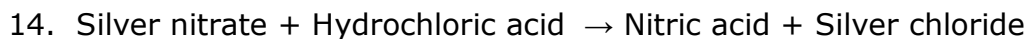
Type of reaction = \_\_\_\_\_



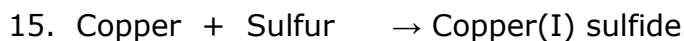
Type of reaction = \_\_\_\_\_



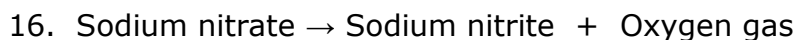
Type of reaction = \_\_\_\_\_



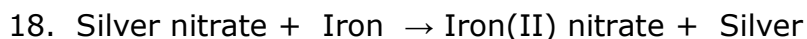
Type of reaction = \_\_\_\_\_



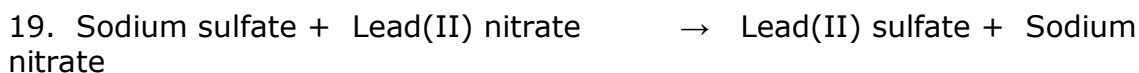
Type of reaction = \_\_\_\_\_



Type of reaction = \_\_\_\_\_



Type of reaction = \_\_\_\_\_



Type of reaction = \_\_\_\_\_

### **Balancing Chemical Equations**

Law of conservation of mass: this law states that in ordinary chemical and physical changes, mass is neither created nor destroyed.

As a result when we write a chemical equation we have to add \_\_\_\_\_ , multiples of the number of atoms in a formula, to balance the equation, or make the reactants equal the products.

### Rules for balancing equations

Identify reactant and products.

If no equation is provided, identify the reactants and products and write an unbalanced equation for the reaction.

If not all chemicals are described in the problem try to predict the missing chemicals based on the type of reaction.

Count atoms

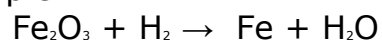
Count the number of atoms of each element in the reactants and in the products and record the results in a table

Pick one element that is not balanced and figure out how you would balance it.

Insert coefficients

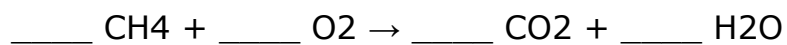
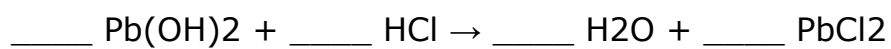
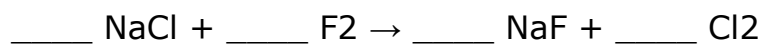
Insert coefficients into the equation to balance the numbers of atoms on both sides of the equations

Example:



	Reactants	Products	Balanced?
Unbalanced equation	$\text{Fe}_2\text{O}_3 + \text{H}_2$	$\text{Fe} + \text{H}_2\text{O}$	
Iron atoms	2	1	No
Oxygen atoms	3	1	NO
Hydrogen atoms	2	2	Yes

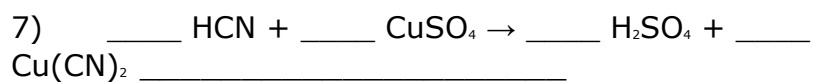
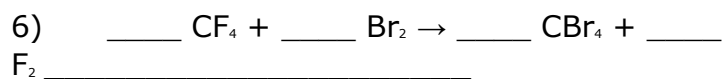
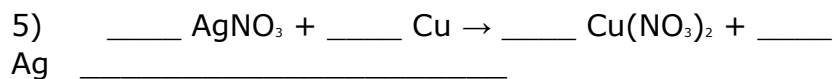
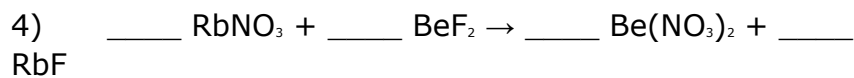
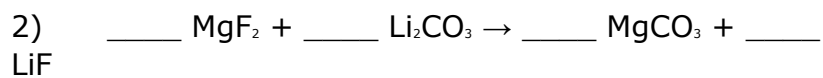
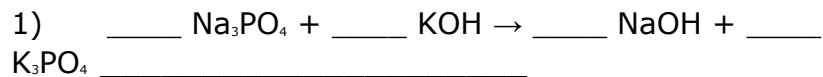


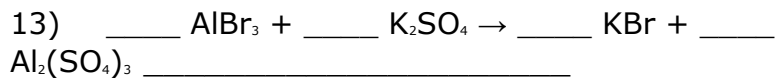
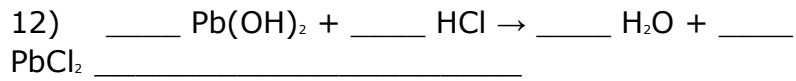
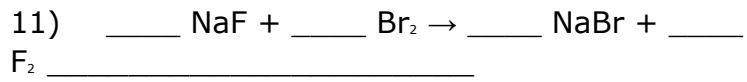
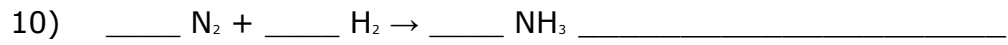
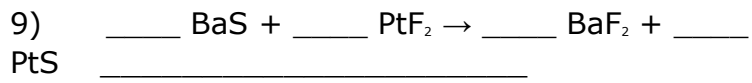
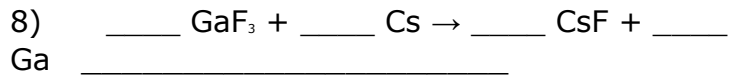


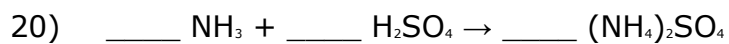
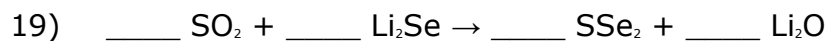
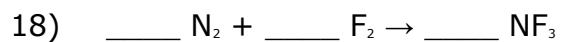
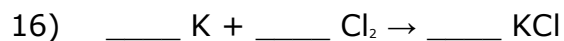
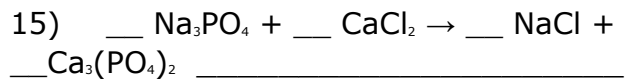
Homework: Balance the equations and page 4, 10, 11, 12

### **Balancing Equations Worksheet**

*Balance the equations below and to the side write the type of chemical reaction*







## TYPES OF CHEMICAL REACTIONS LAB

### *Pre-Lab Discussion*

There are many kinds of chemical reactions and several ways to classify them. One useful method classifies reactions into four major types. These are:

1. direct combination, or synthesis
2. decomposition, or analysis
3. single replacement
4. exchange of ions, or double replacement

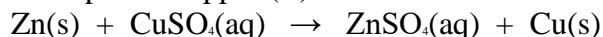
Not all reactions can be put into one of these categories. Many, however, can.

In a synthesis reaction, two or more substances (elements or compounds) combine to form a more complex substance. Equations for synthesis reactions have the general form  $\mathbf{A} + \mathbf{B} \rightarrow \mathbf{AB}$ . For example, the formation of water from hydrogen and oxygen is written  $2\mathbf{H}_2 + \mathbf{O}_2 \rightarrow 2\mathbf{H}_2\mathbf{O}$ .

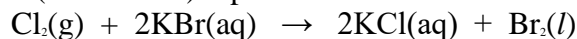
A decomposition reaction is the opposite of a synthesis reaction. In decomposition, a compound breaks down into two or more simpler substances (elements or compounds). Equations for decomposition reactions have the form  $\mathbf{AB} \rightarrow \mathbf{A} + \mathbf{B}$ . The breakdown of water into its elements is an example of such a reactions:  $2\mathbf{H}_2\mathbf{O} \rightarrow 2\mathbf{H}_2 + \mathbf{O}_2$ .

In a single replacement reaction, one substance in a compound is replaced by another, more active, substance (an element). Equations for single replacement reactions have two general forms. In reactions in which one metal replaces another metal, the general equation is  $\mathbf{X} + \mathbf{YB} \rightarrow \mathbf{XB} + \mathbf{Y}$ . In those in which one nonmetal replaces another nonmetal, the general form is  $\mathbf{X} + \mathbf{AY} \rightarrow \mathbf{AX} + \mathbf{Y}$ . The following equations illustrate these types of reactions:

Zinc metal replaces copper (II) ion:

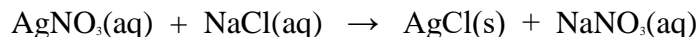


Chlorine (a nonmetal) replaces bromide ions:



In a double replacement reaction, the metal ions of two different ionic compounds can be thought of as “replacing one another.” Equations for this type of reaction have the general form  $\mathbf{AB} + \mathbf{CD} \rightarrow \mathbf{AD} + \mathbf{CB}$ .

Most replacement reactions, both single and double, take place in aqueous solutions containing free ions. In a double replacement reaction, one of the products is a precipitate, an insoluble gas, or water. An example is the reaction between silver nitrate and sodium chloride in which the precipitate silver chloride is formed:



All of the types of reactions discussed here may be represented by balanced molecular equations. Reactions involving ion exchanges may be represented by ionic equations also. In this investigation you will be concerned only with molecular formulas and equations. In a balanced equation, the number of atoms of any given element must be the same on both sides of the equation. Multiplying the coefficient and the subscript of an element must yield the same result on both sides of the balanced equation.

In this investigation you will observe examples of the four types of reactions described above. You will be expected to balance the equations representing the observed reactions.

***Purpose:***

Observe some chemical reactions and identify reactants and products of those reactions. Classify the reactions and write balanced equations.

***Equipment:***

burner  
crucible tongs  
microspatula  
test tubes, 15x180mm(7)  
test tube holder  
test tube rack

wood splints  
evaporating dish  
safety goggles  
lab apron

***Materials:***

zinc, mossy (Zn)  
Copper Wire, 10 cm (Cu)  
magnesium ribbon, 5 cm (Mg)  
copper (II) carbonate ( $\text{CuCO}_3$ )

1 M copper (II) sulfate ( $\text{CuSO}_4$ )  
0.1 M zinc acetate ( $\text{Zn}(\text{C}_2\text{H}_3\text{O}_2)_2$ )  
0.1 M sodium phosphate ( $\text{Na}_3\text{PO}_4$ )  
1 M sodium sulfite ( $\text{Na}_2\text{SO}_3$ )

***Safety:***



Goggles, Aprons and use caution with burner.

In this investigation you will be working with open flames, heating chemicals, handling acids, and producing gaseous products.

Burning magnesium produces a very bright, hot flame. Make sure you hold the burning metal at arm's length and do not look directly at it. Remember never to smell a chemical directly.

Wear safety goggles and aprons at all times when working in the lab.

**Procedure:**

**PART A SYNTHESIS**

1. Get a piece of copper wire from your teacher. Note the appearance of the wire.
2. Using crucible tongs, hold the wire in the hottest part of a burner flame for 1 to 2 minutes. Examine the wire and note any change in its appearance caused by heating.
3. Place an evaporating dish near the base of the burner. Get a piece of magnesium from your teacher. Examine a piece of magnesium ribbon. Using crucible tongs, hold the sample in the burner flame until the magnesium starts to burn. **DO NOT LOOK DIRECTLY AT THE FLAME. HOLD THE BURNING MAGNESIUM AWAY FROM YOU AND DIRECTLY OVER THE EVAPORATING DISH.** When the ribbon stops burning, put the remains in the evaporating dish. Examine this product carefully.



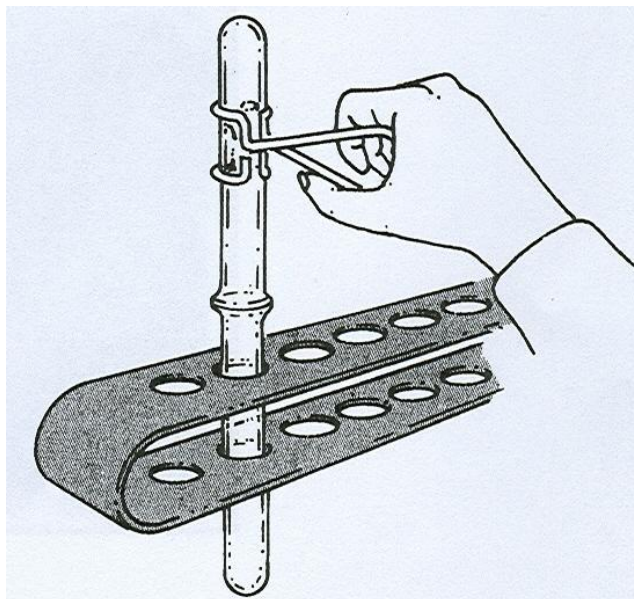
**PART B DECOMPOSITION**

4. Place 2 heaping microspatulas of copper (II) carbonate ( $\text{CuCO}_3$ ) in a clean, dry test tube. Note the appearance of the sample.
5. Using a test tube holder, heat the  $\text{CuCO}_3$  strongly for about 3 minutes. Insert a *burning* wood splint into the test tube. If carbon dioxide gas ( $\text{CO}_2$ ) is present, it will put the flame out. Note any change in the appearance of the residue in the test tube.



**PART C SINGLE REPLACEMENT**

6. Stand a clean, dry test tube in the test tube rack. Add about 5 mL of 3 M hydrochloric acid (HCl) to the tube. **CAUTION.** *Handle acids with care. They can cause painful burns. Do not inhale any HCl fumes.* Now carefully drop a small piece of zinc metal (Zn) into the acid in the test tube.



Observe and record what happens.

7. Using a test tube holder, invert a second test tube over the mouth of the test tube in which the reaction is taking place. See the diagram to the right. Remove the inverted tube after 30 seconds and quickly insert a burning wood splint into the mouth of the tube. (A “pop” indicates the presence of hydrogen gas.) Note the appearance of the substance in the reaction test tube.
8. Add about 5 mL of 1 M copper (II) sulfate ( $\text{CuSO}_4$ ) solution to a clean, dry test tube. Place a small amount of zinc metal in the solution. Note the appearance of the solution and the zinc before and after the reaction.

**PART D DOUBLE REPLACEMENT**

9. Add about 2 mL of 0.1 M Lead Nitrate  $\text{Pb}(\text{NO}_3)_2$  to a clean, dry test tube. Next, add about 2 mL of 0.1 M Potassium Iodide (KI) to the test tube. Observe what happens and note any changes in the mixture.

## OBSERVATIONS AND DATA

*DATA TABLE*

<b>Sample reaction</b>	<b>Before reaction</b>	<b>After</b>
------------------------	------------------------	--------------

---

*A. Synthesis*

1. Cu

2. Mg

---

***B. Decomposition***

3.  $\text{CuCO}_3$

---

***C. Single Replacement***

4.  $\text{Zn} + \text{HCl}$

5.  $\text{Zn} + \text{CuSO}_4$

---

***D. Double Replacement***

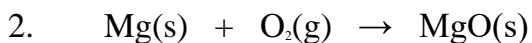
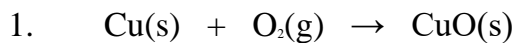
6.  $\text{Pb}(\text{NO}_3)_2(\text{aq}) + \text{KI}(\text{aq})$

**EQUATIONS:**

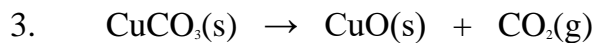
**Balance** each of the equations by inserting the proper coefficients where needed.

**Write the Names** of the reactant(s) and product(s) below the molecular equation for each reaction.

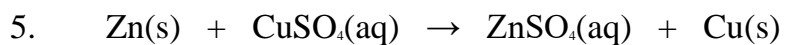
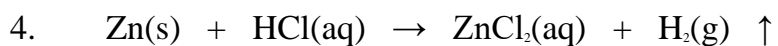
PART A SYNTHESIS



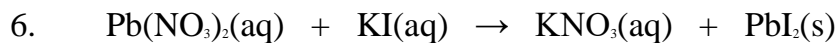
## PART B DECOMPOSITION



## PART C SINGLE REPLACEMENT



## PART D DOUBLE REPLACEMENT

**CONCLUSIONS AND QUESTIONS:**

1. What are the indicators of a chemical change?

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2. Describe what test was used to identify hydrogen gas?

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3. State the law of conservation of matter, How do we show the law of conservation of matter is upheld in a chemical equation?

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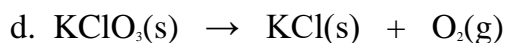
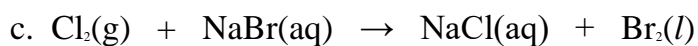
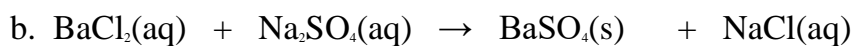
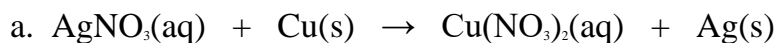
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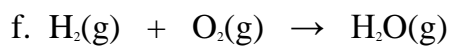
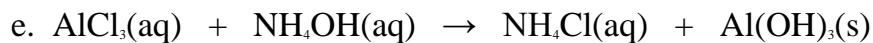
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3. Balance the equations below using the smallest whole number coefficients.

Identify the type of reaction represented by each equation.





## BALANCING CHEMICAL EQUATIONS

Load the simulation *Balancing Chemical Equations*

<http://phet.colorado.edu/en/simulation/balancing-chemical-equations>

### CRITICAL THINKING QUESTIONS

1. Explore the *Balancing Chemical Equations* simulation. Discuss with your group what you find.

a. What are the different ways that the simulation indicates when an equation is balanced?

2. For each balanced reaction, indicate the total number of molecules in the table below.

Reaction	Total Number of Molecules
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	Reactant Side (Left)	Product Side (Right)
Make Ammonia		
Separate Water		
Combust Methane		

3. Is the number of total molecules on the left side of a balanced equation always equal to the number of total molecules on the right side of the equation? Explain your answer.

4. For each balanced reaction, indicate the total number of atoms in the table below.

Reaction	Total Number of Atoms	
	Reactant Side (Left)	Product Side (Right)
Make Ammonia		
Separate Water		
Combust Methane		

5. Is the number of total atoms on the left side of a balanced equation always equal to the number of total atoms on the right side of the equation?

6. What is the same on the left and right side of a balanced equation? Explain your answer.

7. As a group, play level 1 of the balancing equation game. Write down the strategies your group uses to balance chemical equations.

8. Start level 2 of the balancing equation game. Take turns in your group to balance the equations in the sim, using your strategies from Level 1, and adding new strategies as needed.

**Each person should be in charge of balancing at least one equation**, asking for help from the group as needed. As a group, write down the equations as you solve them.

9. In the simulation, were you able to use noninteger numbers (like  $\frac{1}{2}$  or 0.43) for the coefficients in a balanced equation? Why do you think this is?

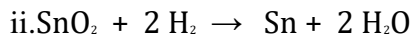
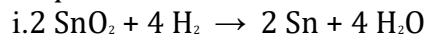
a. Which of the following are coefficients you could use in a balanced equation?

$\frac{1}{2}$         $\frac{3}{4}$        1       2       6       9

b. If you were balancing an equation containing the  $O_2$  molecule, which of the following would be correct representations of  $O_2$  and its coefficient?

$\frac{1}{2}O_2$         $O_2$       $3O_2$         $6O_2$        3O        $5O_3$

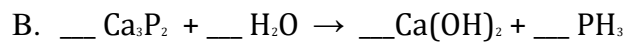
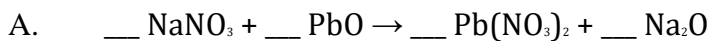
10. What do you have to do to the coefficients of equation I below to get to equation II?

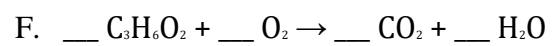
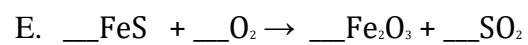
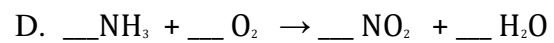


a. Both equation I and II are balanced, but equation I is the correct way to write the balanced equation.

- b. Can you divide equation II by another factor and still have it be correct? Why or why not?
- c. In a complete sentence, write down a method you could use to determine if an equation is written in the correct way.
11. Start level 3 of the balancing equation game. Take turns and write down the equations as you solve them, along with any new strategies you needed for balancing.

**CHALLENGE QUESTIONS: BALANCE THE EQUATIONS BELOW.**



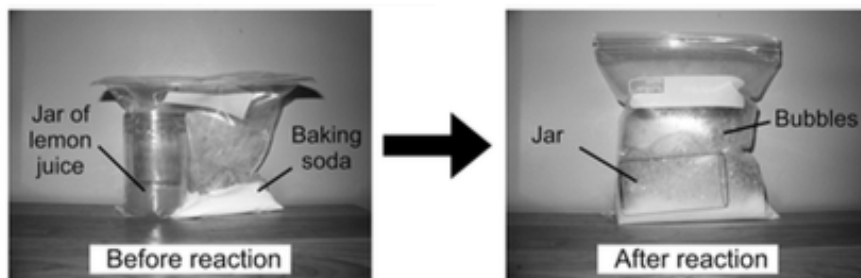


APPENDIX K

AAAS TEST OF CHEMICAL REACTIONS CONCEPTS

## Chemical Reactions Concepts Test

1. Which of the following is an example of a chemical reaction?
- A. Water evaporating from a pot on a hot stove
  - B. Sand being removed from sea water by filtration
  - C. A spoonful of sugar dissolving in a glass of water
  - D. A white solid forming when two clear liquids are poured together
2. A student places some baking soda and a jar of lemon juice in a plastic bag and seals the bag. She weighs the bag and everything in it. She shakes the bag so that the lemon juice spills out of the jar and mixes with the baking soda inside the bag. The student observes that bubbles form and the bag expands.



If the student weighs the bag and everything in it after the bubbling stops and compares the final weight to the starting weight, what will she find out?

- A. The final weight will be greater than the starting weight because new atoms are produced during the experiment.
- B. The final weight will be less than the starting weight because some of the atoms are destroyed during the experiment.
- C. The final weight will be the same as the starting weight because the number of each kind of atom does not change during the experiment.
- D. The final weight will be the same as the starting weight because some atoms are destroyed, but new ones are created during the experiment.

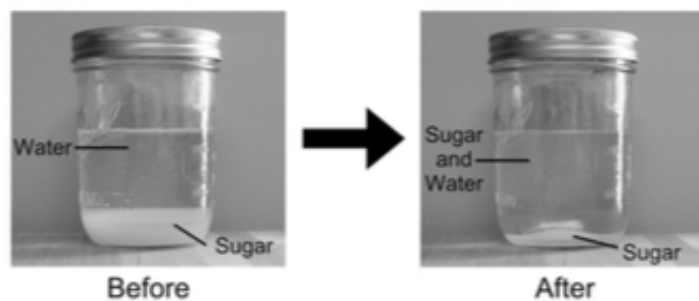
3. A student has two different liquids in open jars. She pours the liquid from one jar into the other jar, and she observes bubbles. After the bubbling stops, she finds that the total weight of the liquids is now less than the total weight of the liquids before they were mixed together.



How can her observation be explained?

- A. Some atoms went into the air.
  - B. Some atoms were destroyed.
  - C. Some atoms became heavier.
  - D. Some atoms became lighter.
4. Which of the following *always* results from a chemical reaction?
- A. Fire
  - B. Bubbles
  - C. A new substance that is a solid
  - D. A new substance that can be a solid, liquid, or gas

5. A student adds water and sugar to a jar and seals the jar so that nothing can get in or out. The student then weighs the jar containing the water and sugar. After some sugar dissolves, the student weighs the jar and its contents again.



What will happen to the weight of the jar containing the water and sugar after some of the sugar dissolves?

- A. The weight will stay the same.
  - B. The weight will increase.
  - C. The weight will decrease.
  - D. The weight will depend on how much sugar dissolves.
6. A chemical reaction is taking place in a sealed container. What will happen to the mass of the materials in this sealed container?
- A. The mass will increase.
  - B. The mass will decrease.
  - C. The mass will stay the same.
  - D. It will depend on which chemical reaction occurs.

7. In the diagrams below, sulfur atoms are represented by gray circles, carbon atoms are represented by black circles, and oxygen atoms are represented by white circles.

Which of the following could be a product of the chemical reaction between sulfur and oxygen?



8. Which of the following is an example of a chemical reaction?
- A. A marshmallow turning black when heated over a fire
  - B. A powder dissolving in water to make lemonade
  - C. An ice cube melting into a puddle of water
  - D. Salt crystals being crushed into a powder
9. Two white powders were mixed together. A chemical reaction occurred, and a yellow powder was formed. What is the relationship between the yellow powder and the white powders?
- A. The yellow powder is made up of the same kinds of atoms as the white powders, but the atoms are combined into different molecules.
  - B. The yellow powder is made up of the same kinds of molecules as the white powders, but the molecules are a different color.
  - C. The yellow powder was released from inside the atoms of the white powders.
  - D. There is no relationship between the yellow powder and white powders.

10. A student mixes two different liquids together. After mixing the liquids, a solid substance forms that cannot be turned back into the starting liquids. The student claims that a chemical reaction occurred. Why is the student correct?
- A. Because a solid substance is always formed during a chemical reaction
  - B. Because a new substance is always formed during a chemical reaction
  - C. Because a chemical reaction always occurs when two substances are mixed together
  - D. Because the products of a chemical reaction can never be turned back into the starting substances
11. A student determines the density, solubility, and boiling point of two liquids, Liquid 1 and Liquid 2. Then he stirs the two liquids together and heats them. After stirring and heating the liquids, two different liquids form, Liquid 3 and Liquid 4. Then the student determines the density, solubility, and boiling point of Liquids 3 and 4. He concludes that a chemical reaction occurred. Here are his results:

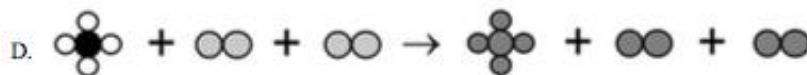
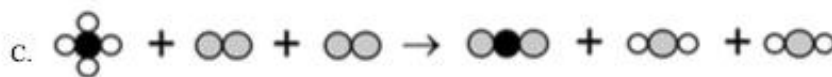
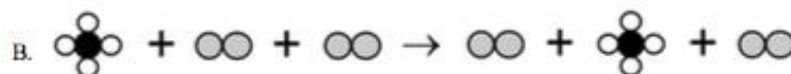
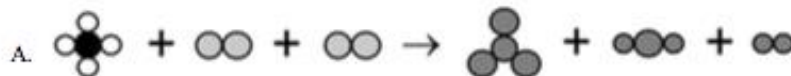
		Density (g/mL)	Soluble in Water	Boiling Point (°C)
Before stirring and heating	Liquid 1	0.96	Yes	164
	Liquid 2	0.81	Yes	118
After stirring and heating	Liquid 3	0.87	Yes	166
	Liquid 4	1.00	Yes	100

How does the student know that a chemical reaction has occurred?

- A. The student knows that a chemical reaction has occurred because Liquid 3 has different properties than Liquid 4.
- B. The student knows that a chemical reaction has occurred because Liquid 1 has different properties than Liquid 2.
- C. The student knows that a chemical reaction has occurred because Liquids 3 and 4 have different properties than Liquids 1 and 2.
- D. The student knows that a chemical reaction has occurred because a chemical reaction always occurs when two liquids are mixed together.

12. Which of the following could represent a chemical reaction?

Atoms are represented by circles, and molecules are represented by circles that are connected to each other. The different colored circles represent different kinds of atoms.



13. Which of the following is an example of a chemical reaction?

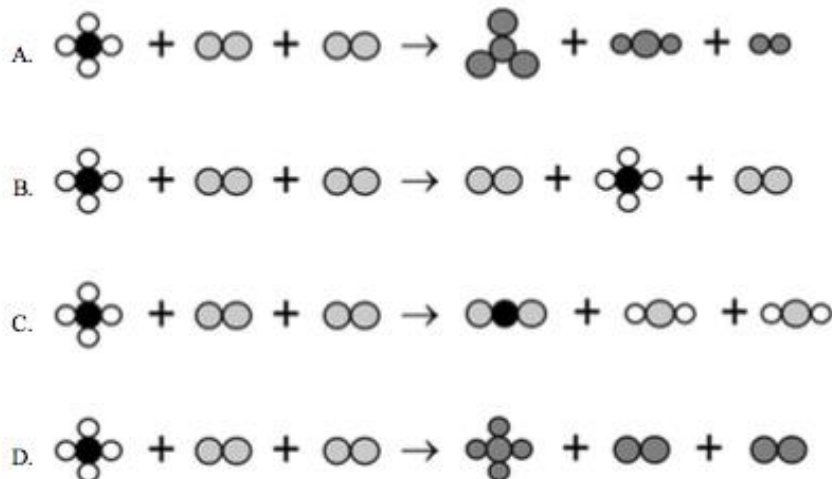
- A. Aluminum foil being cut into smaller pieces
- B. A drop of food coloring dissolving in water
- C. Melted butter becoming a solid when placed in the refrigerator
- D. The surface of a copper penny changing color after being in a drawer for years

14. Which of the following statements about chemical reactions is TRUE?

- A. Chemical reactions produce solids, liquids, or gases.
- B. Chemical reactions produce gases but not liquids or solids.
- C. Chemical reactions occur between liquids but not between gases or solids.
- D. Chemical reactions occur between solids and liquids but not between solids and gases.

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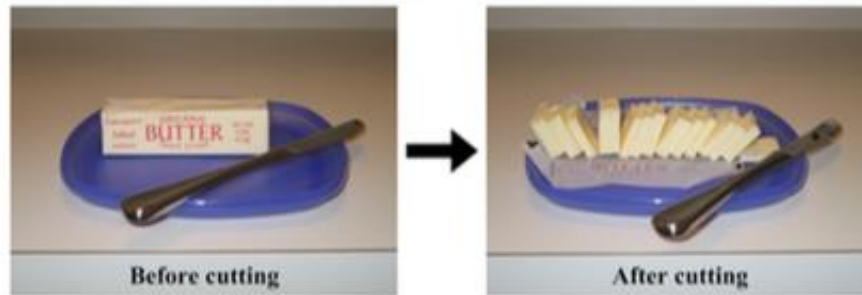
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- D. Chemical reactions occur between solids and liquids but not between solids and gases.

15. Which of the following statements about chemical reactions is TRUE?
- A. Chemical reactions produce solids, liquids, or gases.
  - B. Chemical reactions produce solids and gases but not liquids.
  - C. Chemical reactions occur between liquids but not between gases or solids.
  - D. Chemical reactions occur between solids and liquids but not between solids and gases.
16. Which of the following statements about chemical reactions is TRUE?
- A. All chemical reactions are dangerous.
  - B. Some chemical reactions can be reversed.
  - C. Chemical reactions occur only in a laboratory.
  - D. Chemical reactions require starting with at least two substances.
17. A reaction occurs between two liquid substances in a sealed jar. What will happen to the mass of the sealed jar and its contents after the reaction occurs?
- A. The mass will change if a gas is formed, and it will change if a solid is formed.
  - B. The mass will change if a gas is formed, but it will not change if a solid is formed.
  - C. The mass will change if a solid is formed, but it will not change if a gas is formed.
  - D. The mass will not change if a gas is formed, and it will not change if a solid is formed.

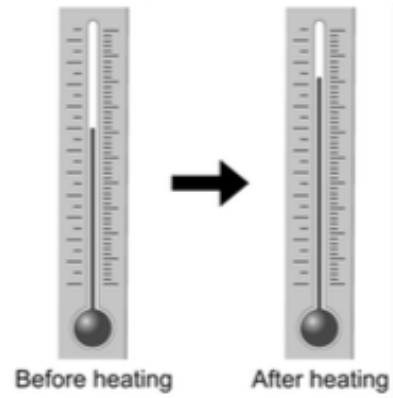
18. A student uses a knife to cut a stick of butter on a dish into smaller pieces. The student weighs the dish, knife, wrapper, and butter before and after cutting the butter into pieces.



Will the dish, knife, wrapper, and butter weigh more, less, or the same when the butter is in small pieces and why?

- A. They will weigh more because there are more pieces of butter.
- B. They will weigh less because the butter is in smaller pieces.
- C. They will weigh less because some of the butter disappears when it is cut.
- D. They will weigh the same because the amount of butter has not changed.

19. A thermometer is heated. The volume of the liquid inside of the thermometer increases, and the level of the liquid rises.

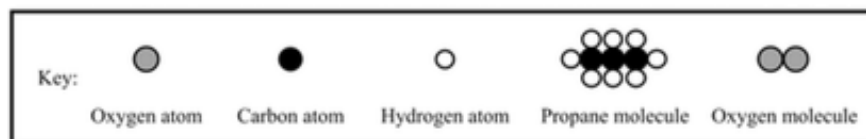


What happens to the mass of the liquid in the thermometer as the level of liquid rises?

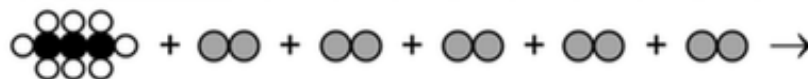
- A. The mass increases.
- B. The mass decreases.
- C. The mass stays the same.
- D. It depends on the type of liquid.

20. In the diagrams below, atoms are represented by circles, and molecules are represented by circles that are connected to each other. The different colored circles represent different kinds of atoms.

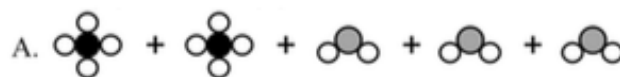
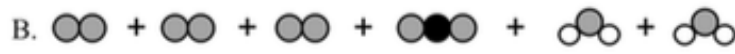
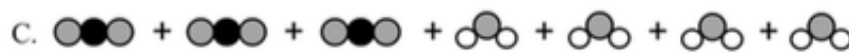

A propane molecule is made up of 3 carbon atoms and 8 hydrogen atoms. An oxygen molecule is made up of 2 oxygen atoms.



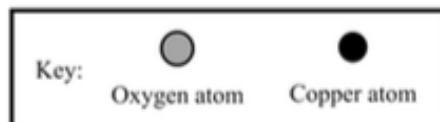
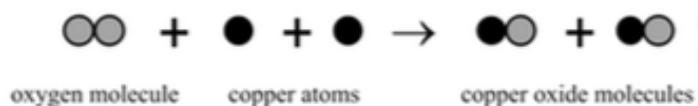
This diagram shows one propane molecule and five oxygen molecules.



Which of the following diagrams could represent the molecules formed when propane and oxygen molecules react?

- A. 
- B. 
- C. 
- D. 

21. When heated, oxygen reacts with copper to form copper oxide.

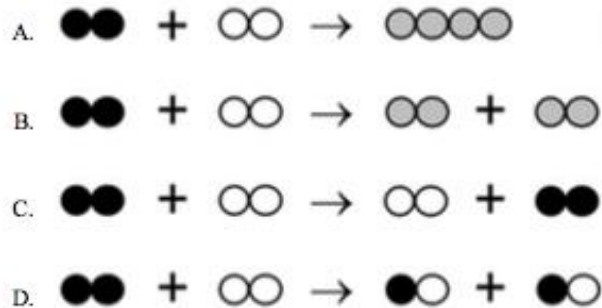


If this reaction occurs in a sealed container, will the mass of the container and everything in it increase, decrease, or stay the same and why?

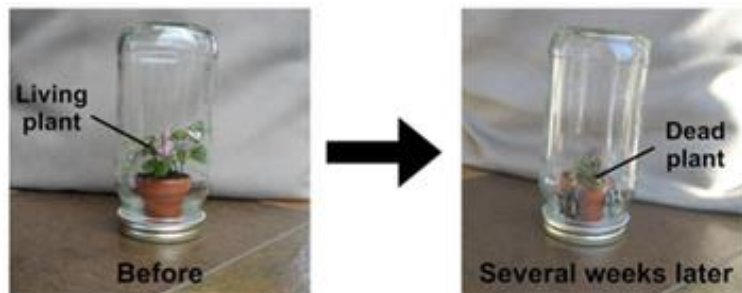
- A. The mass will stay the same because the number of each kind of atom stays the same.
  - B. The mass will decrease because two substances combine to form one substance.
  - C. The mass will increase because a new kind of molecule is formed.
  - D. More information is needed to tell if the mass will change.
22. A student placed a liquid in a jar and sealed it. Then she heated the liquid and it turned into a gas. If the number of atoms in the sealed jar stayed the same, what happened to the mass of the jar and everything inside it after she heated it?
- A. The mass increased.
  - B. The mass decreased.
  - C. The mass stayed the same.
  - D. It depends on whether a chemical reaction occurred.

23. Which of the following could represent a chemical reaction?

Atoms are represented by circles, and molecules are represented by circles that are connected to each other. The different colored circles represent different kinds of atoms.



24. A student places a living plant in a jar and seals it so nothing can get in or out. He determines the total mass of the jar and everything inside it. Several weeks later, the plant is dead.

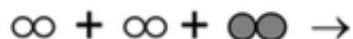


What will happen to the total mass of the jar and everything inside it after the plant dies?

- A. The mass will stay the same.
- B. The mass will increase.
- C. The mass will decrease.
- D. It depends on the type of plant.

25. Which of the following is an example of a chemical reaction?
- A. A piece of wax melting and forming a liquid
  - B. A piece of chalk making white marks on a chalkboard
  - C. Bubbles of gas forming when a seashell is placed in vinegar
  - D. A powder dissolving in hot water to make hot chocolate

26. The diagram below shows molecules before they react in a chemical reaction. Atoms are represented by circles, and molecules are represented by circles that are connected to each other. The different colored circles represent different kinds of atoms.



Which of the following diagrams could represent the molecules that result from the chemical reaction and why?

A.



Because there were 6 atoms before the reaction and 6 atoms after the reaction.

B.



Because there were 2 kinds of molecules before the reaction and 2 kinds of molecules after the reaction.



Because there were 4 white atoms and 2 gray atoms before the reaction and 4 white atoms and 2 gray atoms after the reaction.



Because there were 3 molecules before the reaction and 3 molecules after the reaction.