Exciting Youth about Science and Engineering: The Stirling Engine Class

By

Patrick R. Barragán

SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2008

Signature of Author: ______________________
Department of Mechanical Engineering
Date 5/9/08

Certified by: ______________________
Douglas P. Hart
Professor of Mechanical Engineering
Thesis Supervisor

Accepted by: ______________________
John H. Lienhard V
Professor of Mechanical Engineering
Chairman, Undergraduate Thesis Committee

Exciting Youth about Science and Engineering: The Stirling Engine Class

by

Patrick R. Barragán

Submitted to the Department of Mechanical Engineering
on May 9, 2008 in partial fulfillment of the
requirements for the Degree of Bachelor of Science in
Mechanical Engineering

ABSTRACT

The problem of a lack of science and engineering opportunities for youth has been identified. While other programs and attempted solutions exist, a novel approach involving creating self-contained project classes, called modules, and trading them between institutions is proposed. This idea intends to make these lacking opportunities available while overcoming some of the current problems opposing this availability namely insufficient resources and staff. While limited time and resources prevents the complete testing of the idea, the development of a single module to the point before developing a trading system is implemented. The project chosen is the construction and operation of the Stirling Engine using a design borrowed from MIT course 2.670. The module is tested with 15 4th to 7th grade home-schooled students in Los Angeles, Ca. Observations and participant feedback are gathered. Changes including the shortening of lectures, simplification of the project, and addition of testing are proposed. The information gathered from the test suggests that with a trading system in place, these modules can expose students to science and engineering and generate excitement for the fields.

Thesis Supervisor: Douglas P. Hart
Title: Professor of Mechanical Engineering

Acknowledgements

To all those who made this project possible: God, my family, Douglas Hart, Rohan Abeyaratne and the MIT Department of Mechanical Engineering, Marty Gould and Zen Machine, and my class and their parents.

And finally, to Dave Wottle. I knew I could make it.

Table of Contents

1. Introduction

1.1. The Problem

To further science and technology and their associated possibilities and discoveries, intelligent and talented scientists and engineers must continue to explain the world and explore the unknown. As the scientific community ages, youth will find opportunities to follow in their footsteps and step beyond their accomplishments. However, young people have to not only know of but also be attracted to the opportunities in these fields to be compelled towards them in their careers. Thus, a responsibility exists to excite the youth about the fields.

In the United States, education opportunities for youth in science and engineering are far from pervasive. Many grade schools and high schools have limited quality of science and engineering education let alone opportunities for students to explore these areas. Outside organizations such as FIRST Robotics have created programs to bring opportunities to these age groups. While the cost and ease of implementation of these programs vary, some communities and schools are still unable to bring these possibilities to their students. In some cases, the necessary teaching staff or teaching expertise do not exist to develop and conduct classes in these fields. Additionally, many schools do not have the funds for the materials or work involved with developing or implementing these type of projects locally.

Specifically, the motivation for this project came from a group of home schooled students between the ages of 10 and 13 in Los Angeles, Ca. Home-schooling academies are organizations which bring together local home-school students in different areas to share in certain classes, social activities, and events. Two of these academies, although close in proximity, differed in the science and education opportunities. The larger of the two had a FIRST robotics team while the other lacked the numbers and resources to organize such a program for their students. As home-schooled children with no connection to other schools, the students of this second academy lacked many chances to be exposed to science and engineering topics or get hands-on experience in these fields.

This group of youth provides a concrete example of the problem that must be addressed. Without exposure to science and engineering at this age, these bright children may not choose to follow a path to a career in these fields or even consider exploring them in high school or later. As this is not an isolated situation, the problem of a lack of youth interest in these topics becomes serious. To ensure that a high-level scientific community is sustained, all students must be exposed to science and engineering so that the option of continuing along that path exists for them. Thus, exciting the youth about these fields becomes paramount in promoting the development and expansion of science and technology in the future.

1.1 The Idea

One possible solution to the lack of youth opportunities in science and engineering is creating self-contained project classes which could be partially or completely traded between groups or schools. These self-contained classes, or modules, would address the key features of exposing students to and creating exciting about these fields. In order to do so, the modules would be based around hands-on experiments and a project that preferably involved many scientific topics.

To achieve this, first, a group or school would select one, or more than one, teacher to develop one of these modules. Then, the teacher would choose a project that explored the particularly topics of science and engineering the school hoped to address. The project would be chosen with the previously mentioned key features in mind. After a project was chosen, a list of topics appropriate to the student grade level and associated with project would be formulated.

The topics would be chosen such that the project directly involves the information that the students are learning thereby showing them an application of the material and hopefully creating an interest in the ways scientific topics are involved in surrounding world. A curriculum would then be developed including lectures on the necessary topics, hands-on experiments to explore the topics, and demonstrations to show other aspects of the material that would not be addressed with the other components.

Next, the group or school would fund the creation of project components, the experiments, the demonstrations, and any other materials necessary to conduct the class. The components of the class would be designed to be completely or nearly completely reusable. Finally, the class would be conducted in the group or at the school, and as with any course, the necessary changes would be made to any non-ideal aspect of the original class. With the fully developed curriculum and physical components finished, the module would be completed.

This module addresses creating an opportunity to expose youth to and excite them about science and engineering. However, the previously mentioned problem also contained the complexity of groups and schools being unable to implement or create these opportunities because of lack of teaching staff expertise or resources. Yet, by exchanging these self-contained modules between organizations, this second aspect of the problem can also be overcome.

This solution can best be shown by a simple example. Separated by a few miles, two junior-high schools each have a specific science teacher. At one, the particular teacher has good experience in chemistry from courses taken in college. The other teacher at the other school had majored in physics in college. The two schools both fund the certain teacher at their school to develop one of the self-contained modules. Each teacher designs a curriculum and project that can be taught over half of the academic year. After the modules are finished, each school conducts the class with one of their grades, and any necessary changes are made. At this point the two schools switch modules. Each teacher then uses the other's materials to prepare to teach to other module for the second half of the year. Finally, they both teach the other's module to their class.

This example shows that using these modules finishes addressing the previously mentioned problem. First, both science teachers have general knowledge about the others expertise but concentrated in a different area in their studies. They use their expertise to build a curriculum which the other teacher can then review to prepare him or herself to teach the necessary topics. Thus, each school now has the benefit, in some respects, of having the expertise of both teachers. Also, neither school has the problem of not having adequate teaching staff in either area to instruct their students properly in that discipline.

Second, by only funding the development of one module and then trading the modules, the two schools enjoy the benefit of two classes for the cost of creating one. Each school may not have ample budgets for its science education which would preclude it from developing both classes itself. However, each school may be able to fund one of the classes. Then, instead of only having the one project class it could afford to create, the school, after trading modules, is able to give its students the opportunity to take both classes. In this simple example, trading these modules cuts the schools cost in half.

This idea is extendable to more than this simple example. A network of schools in an area could all create their own modules and a trading system in order to allow their students many more opportunities in science and engineering then would have been possibly for the school's cost to create their module or potion of the modules. Even more complicated possibilities could be implemented. Entire school districts could create programs to create and trade modules or larger government institution could invest in certain standardized module sets which can be reproduced and widely used.

With proper design and implementation, the idea of creating self-contained project classes to be traded between groups or schools becomes a possible solution to the problem plaguing youth opportunities in science and engineering. Including a curriculum, project, experiments, and demonstrations, the properly designed courses would expose students to the fields and generate excitement. Different teachers with different backgrounds would apply their expertise to develop courses with a level of quality potentially impossible for some schools in that topic. Finally, trading the self-contained modules would significantly decrease the cost for each school to have the number of courses in the trading system available. Although the logistics of creating such a system are not trivial, the potential benefits of the system can be extraordinary.

1.2 The Test

This project specifically attempts to develop one of these modules and suggest corrections and improvements. These steps test the previously mentioned system to the point before trading the modules between groups. For logistical reasons and limited time and resources, a trading system for these modules remains untested. Finally, after this test, the effectiveness of the module in meeting the goals of providing science and engineering opportunities to youth that they may otherwise lack and generating excitement for the fields is assessed.

Satisfying the previous criteria for a preferable module project, the project idea chosen was the construction and operation of a Stirling engine, the idea and design of which came from the MIT course 2.670, Mechanical Engineering Tools. First, constructing and operating a

Stirling engine heavily involves the students in an interactive, hands-on way. Second, many, various scientific principles govern the function of the engine. While very complicated in detail, the topics, such as heat transfer, friction, and inertia, concerning these principles can be taught easily in a simplified but informative manner that would be better suited for youth. Because of the nature of the project, sufficient topics could be generated that would be appropriate to teach to young students but also directly relate to the final project as hoped. Next, the previous two satisfied criteria also indicate that this project would expose the students to topics in science and engineering. Through both the hands-on construction and the class topics, the students will gain exposure to many facets of the fields. Additionally, the utilized design of a Stirling engine involves a flame energy source, spinning wheel, and various moving parts. Because of its existence in automobiles, the engine is also a mechanism commonly seen and, at a top level, understood. Therefore, from the view point of younger children, and potentially many other age groups, the construction and operation of the Stirling engine as a project can generate great excitement for the scientific concepts involved and possible extensions into everyday life. Finally, because of the design of this Stirling engine, the engine components could be easily reusable for multiple instances of the class. However, in this case, the students kept the engines as only one test of the module was intended. With all of these aspects considered, this project choice properly satisfies the criteria for a preferable module project.

A curriculum including experiments and demonstrations was to be developed to teach the previously mentioned concepts related to the construction and operation of the Stirling engine. Because the engine becomes the centerpiece of the course, all aspects of the curriculum should be designed around the project and be directly applicable to the project. Similar to the project itself, the experiments and demonstrations should together provide hands-on exposure to the scientific concepts being taught to reinforce the material given during lectures and create excitement about the topics.

2. The Case Study

2.1. Participation, Time Frame, and Location

The case study was conducted in Los Angeles, Ca during the summer months, June, July, and August, of 2006. For this test, the age group chosen was students in the 4^{th} through 7^{th} grades. Generally, these students were between the ages of 10 and 13 years old. The majority of students were home-schooled and involved in various, local home-schooling academies although a few students were from local elementary and junior high schools. Because of limited funds and the single teacher, 15 students officially participated in the class although some interested siblings also listened to the lectures and participated when they could. Again, due to limited resources and because many of the students already had home-school experience, the author's house in Los Angeles was used as the classroom. The class was conducted for 2 hours each Wednesday of the 12 weeks of the summer. Approximately half of the class time was used to lecture on the scientific topics of the week while the other half was used for demonstrations and class experiments.

The author entirely developed the curriculum and organized and conducted the class. Funding in the amount of $4000 was secured from the MIT Department of Mechanical Engineering through the department head Rohan Abeyaratne. Information about the course 2.670 and contacts concerning the MIT designed Stirling engines were provided by mechanical engineering professor Douglas Hart. 15 fully machined MIT design Stirling engines were acquired through Marty Gould of Zen Machine. Unlike those in 2.670, these engines were machined to be fully prepared to assemble as the age and inexperience of the young students in the case study class would make student modification or machining of the engine nearly impossible. Additionally, all parents who could often stayed for the classes to listen to the material and assist the students with questions and problems during the class experiments and assembly of the engines.

2.2. Curriculum

The curriculum of the test module was designed around the intended half-lecture, half-experiment or demonstration structure of the classes. Some classes were entirely lecture with a short demonstration but the majority involved an experiment or demonstration to reinforce the topics of the day or generate additional excitement about the topic. In the first class period, the topic of the scientific method was covered to motivate the format of all experiments done in the class. This addition was meant to start the students along a scientific approach and thought process when encountering technical questions.

Shown in Appendix A, to be prepared to fully explain the operation of the engine at the end of the course, the following topics were covered: mass, density, volume, area, inertia, force, energy, phases of matter, pressure, gas laws, heat transfer, friction, the scientific method, and elementary thermodynamics. To reinforce these topics, experiments on weight and density, conservation of energy, kinetic friction, gas laws, and heat transfer were conducted. Five copies of each experimental apparatus were constructed to ensure small groups of students, approximately three for each setup, had close hands-on interaction with the tests. The students were asked, when possible, to switch tasks during the tests to expose each student to all aspects of the experiment.

Each of these experiments addressed at least one if not more than one topic. For example, the conservation of energy experiment involved a toy car on a ramped track. The students would place the car at different heights on the ramp and release it. They would then measure the distance the car traveled for each height and attempt to relate, at a high level, the height of release to the distance traveled. This experiment related to the topics of potential and kinetic energy and energy transfer but also friction, the involvement of which must be included to explain why the toy car eventually stopped in each case.

Multiple demonstrations were conducted during the course. Unlike the experiments, these demonstrations were too complex or dangerous for the students to conduct themselves. Instead, the teacher showed the demonstration and then explained the governing principles and their relation to topics previously covered. For example, the classic experiment to boil water with an ice cube was shown. The idea is to boil water in a volumetric flask. Water vapor pushes the air out of the flask, and the flask is sealed with a cork. At this point, the water vapor occupying the remaining space that the liquid does not occupy remains at a pressure such that the rest of the water will not boil and the water vapor will not condense. Flipping the flask over and placing ice cubes on the now top side causes the water vapor to decrease in pressure. This decrease in pressure allows the remaining water to begin to boil. This demonstration and following discussion was used to better illustrate the gas law concepts to the students while using an interesting example that would hopefully be more memorable.

Because the class was composed of young students and hoped to create a hands-on learning experience, student interaction during the lectures and experiments seemed paramount. Students found involvement in lectures by having to answer many questions and even participating in explanations of the material. For example, when explaining the relationships between pressure, temperature, volume, and mass of a gas, the students themselves were used to simulate the gas molecules. A ring of students was used to make a "containment vessel." Then, initially a few and later many of the remaining students were asked to walk around inside of the ring and only change directions when colliding with the ring or another student. The students found that with more of them in the ring, they would have "collisions" more frequently. To simulate a temperature increase, the students were told to walk faster and found that again they had "collisions" more frequently and more intensely. Through this student demonstration and a following discussion, the observed and remaining relationships between the variables were formally introduced. This method was used with the intent to maintain interest and excitement in the topic and provide an example more easily remembered by the students.

Similarly, the experiments were formulated to require the students understanding and input. As shown in Appendix A, along with the experiment instructions, question and answer sheets were distributed that had to be completed by the students. The experiments thus required the students to conduct each test with little to no adult interaction, record the results, and answer the simple questions about the steps of the scientific method related to their findings. By having to follow the scientific method for each experiment, the students were exposed to using this approach to answering questions. Again, the use of this approach to experiments hoped to maintain interest in the topics, provide a memorable example of the concept, and create a hands-on learning environment for the students.

The course culminated with its centerpiece, the construction and operation of the Stirling engine. The final class lecture explained the four stage Stirling engine cycle by explaining the governing principles of each stage and the engine as a whole through the application of the previously explained class topics. In this way, all of the course topics were directly applied to the engine project with the intent to boost the importance of understanding the individual topics in route to understanding the operation of the possibly more interesting and exciting engine.

During the final two class meetings, the students, with the help of the teacher and parents, assembled and ran the engines. One difference between the proposed module plan and this implementation was that because the class would be the only test of the module, the students were allowed to keep their engines. As a small edition, one class period was used as a field trip to the Jet Propulsion Laboratory in Pasadena, Ca with the intent to provide the students with additional exciting, real-world examples of the applications of science and engineering.

3. Results and Discussion

3.1. Observations

Some aspects of the class implementation worked more effectively than others. First, many lecture sections seemed too long for the young students. Often, students were able to concentrate on the top for only approximately 30 minutes. Many times, at this point, students would begin to show signs of not concentrating such as whispering, looking in various directions, or playing with objects in front of them. As this course was the first formal experience of the teacher with instructing young students, the ability of all of the students to concentrate for the initially intended hour-long lecture sections was assumed and proved incorrect. As mentioned previously, asking students questions and using students to demonstrate concepts were methods used to help the young students maintain concentration on the topic and make the lectures more enjoyable. Stretching breaks were also used for similar reasons. Although these attempts did help mitigate the problem, the students till showed signs of loss of concentration at times, especially near the end of a lecture section.

The experiments and demonstrations appeared to work as intended, to create interest and excitement about the topics as well as reinforce the concepts. All the students seemed to enjoy the experiment and demonstration sections of the course. For each experiment, the students were all involved in using their test apparatus and answered all of the asked questions related to the tests. Again, recording these answers, responses to each step of the scientific method, exposed the students to this approach to answering technical questions, a thought process which will hopefully stay with the students in the future. Also, being required to answer each question on his or her own, each student would have to attempt to understand the concepts involved with the experiment. The demonstrations and experiments both shared the quality that the result of the concept application was shown to the students instead of merely told to them. All of these aspects seem to aid the students in making the intended simple conceptual connections.

For example, in the previously mentioned potential versus kinetic energy experiment, the students were hoped to fully understand energy conversion. Obviously, the concept is if the toy car was released from a higher point and thus started with more potential energy, the car would have more kinetic energy at the bottom of the ramp which would lead to the car traveling further before friction dissipated the kinetic energy of the car. After the lecture and experiment, the teacher asked for the individuals to read their answer to the conclusion question for this experiment. Lending encouragement to the effectiveness of the experiment, the students, through their various answers, demonstrated that they understood the concept. Overall, the loss of student concentration seen in lecture sections was absent from the demonstration and experiment sections of the course. This result suggests that course sections with heavy student involvement and hands-on exposure to the concepts greatly increases concentration and helps student understanding of the concepts.

As intended, throughout the class, students showed great excitement for constructing the engines, yet for some students, this excitement distracted them from concentrating on the class topics necessary to understand the engine operation. The excitement of the students about the end of the class when the engines would be built and run suggests that the Stirling engine satisfied the desired criteria of creating excitement for science and engineering. However, the level of distraction of some students also suggests a lack to sufficient motivation to learn and understand the course topics as an avenue to truly understanding the science behind the Stirling engine and not merely just building a toy.

The students appeared to greatly enjoy the end of the class including building and running the engines and visiting the Jet Propulsion Laboratory. With little to no distraction, each student concentrated on building their engine. The students appeared to greatly enjoy not only the assembly but also the running of the engines. On the trip to JPL, the students also seemed very excited about the different displays and topics that the tour guide spoke about. The level of enjoyment in both of these aspects of the class seems to indicate that this avenue of exposing students to the fields of science and engineering created the desired excitement about the fields.

One potential large difference between this implementation of the module and the general module idea is the presence of many student parents throughout the class. Because many of the students were home-schooled children, many parents naturally listened in on the class and helped where possible. This help proved very useful during experiments and the assembly of the engine when the number of questions from the students was too great for one teacher. Because of the project-based nature of the modules, this situation may be a repeated case in many different implementations. Thus, the usefulness of the parents suggests that for certain portions of the class implementations, additional assistants may be necessary depending on the age group of the students.

3.2. Changes

As intended by the class implementation procedure, after the initial instance of the class, changes should be suggested and carried out to reach a more final version of the course before the module is "packaged" for trading. Because of the situations observed, many suggested changes arise to possibly improve the class in the future. This step in the module design proves crucial as a course often is not perfect the first time it is taught.

One large problem emerged as the lack of student concentration during sections of the class. This problem may be improved by shorter lecture sections or possibly shorter more frequent class times. Increased numbers of experiments and demonstrations may also help the students focus on the material. However, because of limited time, these experiments and demonstrations would have to be very efficient to teach a significant amount of material for the time necessary to conduct them. The subjects taught may need to be shifted more for different age groups. The youth of these specific subjects may have made some of the topics related to the Stirling engine very difficult to understand. Often, the hardest topics confuse students, making them more prone to lose concentration. Thus, simpler topics related to a simpler project may be necessary for this age group.

Although these specific students, through the questions during the class, seemed to attempt to fully understand the material, more motivation could be generated to truly learn and understand the class topics. Using more real-world examples, current events, and age-group specific examples may improve the students' connection to the material thereby increasing their motivation to understand. One aspect that lacked from this instance of the class was that no student received any type of credit for the course. While these particular students still gave great effort despite no formal credit, students at a traditional school may have more motivation to learn the topics if the class is counted. Along these same lines, quizzes or tests, which were not used, may make the students more accountable for the material. However, for students of this age, the components would also raise the stress level in the class and may possibly detract from the intended excitement generated about science and engineering.

Finally, changing the project implementation and the project itself may improve the course as a whole. First, a simpler assembly than the Stirling engine may be desirable as it would be cheaper and easier to construct. The 15 Stirling engines purchased cost three fourths of the budget, or $3000. Also, assembling the engines with the young students took two full class periods and required parent help to complete in a timely fashion. Thus, a simpler project idea or a simpler Stirling engine design may lower costs and complexity. Also, this type of project may be better suited for an older group of students who may have less trouble with the complexity. Second, reorganizing the lectures and experiments around the Stirling engine itself may improve the understanding of the concepts in relation to final project and reduce the complexity of the assembly. If each lecture topic at the time of instruction was related to the engine, the students may have a better grasp of the function of the engine by the end of the course. Instead of attempting to remember all of the material at the end to understand the operation of the engine, the students could see how each topic applies individually. Also, possible constructing different portions of the engine throughout the class or possibly using this construction as the weekly experiment could help students better understand the individual components of the engine and break up the relatively complex assembly of the engine. Careful design of experiments around the project components would be essential, and all projects or topics may not lend themselves to this type of implementation.

3.3. Participant Feedback

Some time after the completion of the course, the students and parents were asked to give feedback about the course in relation to what they enjoyed or did not enjoy, if the class excited the students about science, and various other related questions. Some of their comments are included here to give user, and not just instructor, opinions about the effectiveness of the class components.

Some comments reinforced the idea that a lack of science and engineering students exist for youth. When asked about how easily she has been able to find other opportunities in these fields besides the class, a mother of two of the students, Maria Couce, said, "I would really have to search for something out there that is not only available but in close proximity to us and additionally that would be affordable to us." This statement suggests that location and cost prove to be important factors in finding this type of education. When asked the same question, Joan Judy, another mother of a student, said, "No – [I] haven't had any other opportunities arise and [I] [haven't] had the time to search for them!" These statements reinforce the existence and severity of the problem that this project idea attempts to address.

Other comments suggest that the class, although making a positive impact, did not directly make all of the students want to become scientists and engineers. As an example against the pervasiveness of the problem, some students may already have been exposed to science and plan to follow a career path in the field. For example, one student, Liam Thompson, said, "This class taught me a lot about engineering. It was also very interesting and fun. I just love science, and this is no different." While the student enjoyed and learned from the class, the class does not appear to be a focal point to introduce the fields to him. The class motivated certain students in some ways and not others. Another student, Alisa Couce, said "I am excited about science except I am not very interested in the engineering part. I might be a doctor when I grow up."

Additionally, some students, although enjoying the class and the fields, do not plan to have a career in science and engineering at all. Melody Symonds, a mother of two of the students, said that her son Elijah hoped to be an accountant or lawyer when he grows up. In reference to her son, she said, "He found the class extremely helpful in furthering his understanding of science. He now wants to build more things [...]." In these examples, although the class was enjoyable to many of the students, it may not have been a driving force for some students to a career in science or engineering.

Conversely, the class caused a positive influence for science and engineering for some of the students. Commenting about her son, Joan Judy said, "Kyle wants to be involved in science as a career, and the class boosted his interest in science in general." Promoting their interest in the topics, the class appears to have influenced some students towards a possible career path in the fields. Additionally, the class seems to have given some students a better understanding of science and engineering in general. This exposure may be paramount in these students' further exploration into these fields in the future and consideration of possible career paths. Luke Couce, another student, said, "I didn't really think about it or really know what an engineer was because I never thought about it until I took the class. It made me excited, and I might want to be an engineer like [the teacher]." With some students, the class seems to have met its intended purpose of exposing youth to science and engineering and generating excitement for the fields.

4. Conclusion

Although an implementation of the entire idea of the design and trading of modules was not possible, this test of a portion of the overall idea seemed to achieve the goals of the project. The initial problem to overcome was a lack of science and engineering opportunities for youth. From observations during the class and comments gathered afterwards, this course exposed the young students to the fields and generated excitement about them. Although possibly not the focal point of every students introduction to and enjoyment of science and engineering, the class appeared to have an overall positive influence towards further consideration of the topics and applications introduced. As predicted, many aspects of the course could be changed and hopefully improved for future iterations. The process given for developing these modules appears sufficient, and the possibility and implications of developing a trading system for these modules seems real. Overall, this project demonstrates one avenue to create more widespread opportunities for youth in science and engineering.

Appendix A

A.1Lecture Topics

A.1.1 Mass, Volume, Density, and Area

1. Mass/Volume/Density/Area

Definitions:

Matter:	The thing everything is made of.
Mass:	The amount of matter in something.
Volume:	The amount of space that something takes up.
Ratio:	The relative amount of one thing compared to another thing.
Density:	The ratio of mass to volume.
Area:	The space something takes up on a surface.

Mass:

Mass is the amount of matter in something. Matter is what makes up everything around us. Buildings, clothes, toys, cars, and everything else is made up of matter. Mass is just a measure of how much matter is in something.

Weight is sometimes confused with mass. But the two are not the same. Weight depends on the gravity that acts on the mass. So the weight of something depends on the gravity where the thing is. For now, you can think of gravity as just something that causes weight. Gravity is different on different planets and different places. So because gravity changes, something's weight can change without changing the thing itself. But the mass of something cannot change without actually changing the thing itself. So weight is just a measure of the amount of mass something has and it depends on the gravity where that something is. But mass and weight are related. If gravity is the same for two things, the one with more mass will weigh more as well.

Volume:

Volume is the amount of space something takes up. Just like mass, everything has volume. A baseball takes up more space than a tennis ball so a baseball has more volume than a tennis ball.

Density:

Density is the ratio of mass to volume. A ratio is the relative amount of one thing compared to another. So density is a measure of how much mass something has compared to its volume. In other words, density is a measure of how much matter is in an object compared to how much space it takes up. Think about a balloon and a brick. If a person blows up a big balloon, it might be bigger than the brick. Thus is might have more volume. But the brick has a lot more matter in it. It has a lot more mass. Remember that the brick weighs more than the balloon, and so it has more mass. So the balloon has a small mass but a large volume, and the brick has a large mass and a small volume. So because density measures how much mass something has compared to the volume it takes up, the brick has a high density while the balloon has low density.

Area:

Area is the amount of space something takes up on a surface. Think about a square drawn on a piece of paper. That square has a certain amount of the paper inside of it. The area of the circle is that amount of the paper that is inside of it. So think about drawing a larger square around that square. The second square will have a larger area than the one inside of it because more the surface it is on, in this case, the paper, is inside of the square. But the surface does not have to be flat. If someone picked up the paper and wrapped it around a cup, the person could still see the squares and they would have the same area, but the squares would not be drawn on a flat surface.

A.1.2 The Scientific Method

2. The Scientific Method

Definitions:

Hypothesis: An answer to a question without knowing exactly what the true answer to the question is

Experiment: A test of a hypothesis to determine what the true answer to the question is.

Conclusion: The thing that can be determined from an experiment.

The Scientific Method:

The Scientific Method is the steps that scientists take to determine the answer to a question. In the world, scientists try to find out the answer to many questions. The steps to the scientific method are as follows:

- **Find out what the question is:** What is the question that the scientist is trying to answer. Before any more steps can be done, the scientist must know exactly what this question is.
- **Create a hypothesis:** The scientist must know try to make a hypothesis. In other words, the scientist has to try to answer the question with his or her best guess even though they do not know the exact answer.
- **Do an experiment:** The scientist must now come up with an experiment to determine the answer to the question. The experiment is just a test to figure out the answer to the question. The experiment can be anything that will give the scientist a conclusion:
- **Make a conclusion:** The scientist must reach a conclusion. A conclusion is what is determined from the experiment. It can be the answer to the question. But not all experiments give the answer to the question. Sometimes the conclusion is that the answer cannot be found with this experiment or that other questions have been found during the experiment that must be answered themselves. Overall, the conclusion just gives what the experiment determined.

Scientists use the scientific method to answer every question that does not yet have an answer.

A.1.3 Force

3. FORCE

Definitions:

Object: Something that can be touched or held.
Force: A push or a pull that causes a change of motion on an object of *mass* (see **Mass/Volume/Density/Area**)

Force:

Force is something that causes a change in motion. Anything that can be grabbed or held is an object. Force is a push or pull on an object. That push or pull is what causes that change in motion. For example, a block sitting still on a table will begin to move if it is pushed by someone's hand. The same will happen if it is pulled. It would begin sitting still and then start moving. But it does not have to be sitting still to change its motion. If the object begins to move by pushing it and then it is pulled, it will change directions. The block would move forward and then move backwards. Both times its motion was changed by pushing or pulling on it. A force can also change what direction an object is going in. A block can be pushed forward and then to the right. In fact, it can be pushed and pulled all over the table in any direction. It can even be picked up and put down. So the object can move up, down, left, right, forwards, and backwards. It can move in any direction. The way the object moves is by pushing or pulling on it in any direction.

Remember that a push or pull that may change the motion of an object is a force. There is a force put on this block. In that way a force is applied to the block. Applying means to put something on something else. So something applies a force to something else.

Sir Isaac Newton first explained what force really is. He was a physicist which means that he studied how the world works. One thing that he did was to explain gravity. Gravity is the thing that keeps something on the ground. When someone jumps, he or she goes up and then goes down. Gravity is what pulls the person back down to the ground.

Remember that a force is a push or a pull on an object that may cause a change in motion. Gravity causes a force on a person's body because that person's body is an object and gravity pulls him or her back to the ground after jumping. So that person is just like the block, and gravity is like a person's hand. The block is somewhere, and then someone pulls it to move it. A person is in the air, and gravity pulls that person back to the ground. So gravity pulls a person down just like that person can pull the things. But how does a person get off of the ground to begin with? Let's think about a child named Steve. Steve began just standing there not moving. Then after jumping, he was suddenly moving up into the air until gravity pulled him back to the ground. So that means that he did something that changed his motion from standing still to flying through the air. Steve used his legs to jump, and when jumping, he just pushed on the ground. Well if he changed the motion of his body by pushing down on the ground with his legs, he must have put a force on the ground. So to jump, he put force on the ground to move himself into the air, and then gravity put a force on him to pull him back down to the ground. Again, force is a push or pull on an object that may cause a change of motion. So both his legs and gravity somehow applied a force on his body when he jumped.

So when a block is pushed forward, it moves forward. When it's pushed backwards, it moves backwards. When it is pushed left it moves left, and when it's pushed right, it moves right. Thinking about that, it becomes clear that the direction a force is applied is the direction the object that the force is applied to will move. So if Steve is in the air, and gravity pulls him down to the ground again, the force of gravity points down because it moves him down.

Steve pushed on the ground to jump. The direction he pushed is the direction the object he pushed on should move. He was pushing on the ground, and the ground is part of the earth. But it was Steve who moved when he pushed on the earth. It does not seem like the earth moved.

So another thing the Sir Isaac Newton figured out is that when someone pushes something, it pushes back with the same amount of force as was applied to it. Think about pushing on a wall. A person pushes on it but that person can feel on his or her hands that there is something there pushing back. So when Steve pushes on the ground, the ground pushes back on him.

But Sir Isaac Newton also figured out one other thing about force. He said that what a force will do to an object depends on the mass of that object. When people throw balls, they apply a force to that ball because they change the balls motion. First, remember that if something weighs less than something else on Earth, it must have less mass than that other thing. Think about throwing a ball that is very light weight like a baseball or a tennis ball. A person could probably throw that ball far. But then think about a ball that is made out of metal or cement and is very heavy. If the person tried just as hard to throw the second ball, that ball would probably not go as far. The same force applied to something heavier will not move that thing as far. Also, to move both balls in the same way, more force would have to be applied to the heavier ball.

Going back to the example of Steve jumping, the earth is so big it does not move very much from Steve's push, but he move a lot from it pushing back on him. He pushes down so the Earth pushes up with the same force. This moves Steve up. The same thing happened with the block. When a person pushes it, it actually pushes back against that person. But the person is much bigger than it so it does not move the person much but it moves a lot.

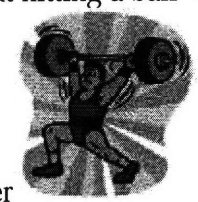
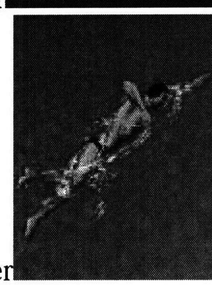
To summarize, these are Newton's three laws:

- An object in motion will stay in that motion unless a force is applied to it. Remember, sitting still is a type of motion. This is another way of saying force causes a change in motion of an object.
- A force will affect the motion of an object of little mass more than an object with a lot of mass. Think about Steve jumping on the earth.
- When something applies a force to something else, it also feels a force on itself in the opposite direction.

So remember two more things. First, a force causes a change in motion of an object, and second, the change of motion of the object happens in the same direction the force is applied in.

Now that force has been discussed, the discussion of mass and weight can be finished. Before discussing force, gravity was just something that caused weight, and it could be different on different planets or in different places. Now you can think of weight as a force that points down. The more an object weighs the more force it applies to the ground below it. This is why it is harder to pick up something heavier. If weight is a force that points down, then to pick something up, a person must apply at least that amount of force up to move it off of the ground. Think about it in a different way. Think about a large block on the ground and one person on each side of it. The person on the left wants to move the block right, and the person on the right wants to move the block left. If they both start pushing on the block, the person who pushes with more force will win and the block will move in the direction that the winner wanted. So thinking about picking up a block, since gravity is pushing the block down, a person needs to apply at least the amount of force that gravity is applying, which is the weight of that block.

So here are some examples of forces.

- Baseball bat hitting a ball 
- Weightlifter 
- Skydiver 
- Swimmer 

A.1.4 Inertia

4. INERTIA

Definitions:

Tendency: The chance that something will be a certain way.

Property: Something that describes a particular thing or set of things that is always true for that kind of thing or set of things.

Inertia: The tendency of an object made of *matter* to remain in the motion that it is in. Inertia is a property of matter.

Inertia:

Inertia is the tendency of an object made of *matter* to remain in the motion that the object is in. Tendency is just the chance that something will be a certain way. If a person always drives to work on one particular street, then they have a high tendency to drive to work on that particular street. At the same time, they have a low tendency to drive to work on a different street.

If a block is sitting still, its inertia is its tendency to remain still. If a block is moving at some speed in some direction, its inertia is its tendency to keep moving at that speed in that direction. One thing Sir Isaac Newton said about *force* was that an object in motion will stay in that motion unless a force is applied to it. That is another way of saying force causes a change in motion. Inertia is just the thing that all *matter* has that causes it to stay in its motion unless a force is applied to it.

Inertia relates to matter and mass. Inertia only exists because of *matter*. A property is something that describes a particular thing or set of things that is always true for that kind of thing or set of things. Every piece of matter in the universe has inertia. So we can say that inertia is a property of matter. All that means is that anything made out of matter, anything that has mass, also has inertia.

Inertia can be described by how much mass an object has. If the mass is greater, the inertia is greater. So if inertia is the tendency to remain in a kind of motion than if the inertia is greater, than the tendency is greater to remain in a kind of motion. This goes along with the second thing Sir Isaac Newton said. He said a force will affect the motion of an object of little mass more than an object with a lot of mass. This makes sense because the object of little mass has a smaller tendency to remain in its motion. A force can more easily change its motion.

Think about a large block and a small block sitting on the ground. If a child came up and tried to push the large block it would be harder to move than the small block. This is because the large block has more mass. If it has more mass, then it has more inertia. If it has more inertia, then it has a higher tendency to remain in its motion. Since its motion is sitting still, it has a higher tendency to sit still even when the child pushes on it. The child has to put more force on it to make it move.

Think about one more example. If someone flips over a bike and spins its wheel, the wheel will go on for along time until something makes it stop. There is some force that eventually makes the wheel stop. But the wheels tendency to keep spinning, which is its motion, is the wheels inertia.

Just remember, inertia is how much an object is going to try to keep doing the same motion it was doing. If an object has greater mass than another object, it will also have greater inertia than the other object.

A.1.5 The Phases of Matter

5. The Phases of Matter

Definitions:

Phases of Matter:	The phases of matter are the different ways in which *matter* can be.
Particle:	A tiny piece of something.
Atom:	The tiny particles which are the building blocks that make up matter.
Collision:	Two or more objects running into each other.
Gas:	The phase of matter in which the atoms are most spread apart and are almost completely free to move without being affected by the atoms around it. Gases generally have low densities.

Liquid:	The phase of matter in which the atoms are closer together than the atoms in a gas and can pull and push on each other more than the atoms of a gas can. Liquids generally have higher densities than gases.
Solid:	The phase of matter in which the atoms are very close to each other and actually packed together in a certain arrangement. The atoms in a solid can push and pull on each other very strongly and have a strong effect on the motion of the atoms around them. Solids generally have higher densities than liquids.
Bond:	Two atoms holding on to each other.

Gas:

A gas is one of the phases of matter. A gas is made up of little *particles* called *atoms*. These atoms are mostly free to fly around without being affected by the other atoms of the gas. But sometimes the particles of a gas run into each other. When they do this, the atoms are said to have had a collision. Also, the atoms exert small forces on each other when they are close. This means that the atoms in a gas pull on each other. But the density of a gas is generally low. This means there are very few atoms flying around so the atoms fly around mostly free without feeling the other atoms pulling on them because they do not usually get close to each other.

Liquid:

A liquid is another phase of matter. Liquids are also made of atoms, because all matter is made of atoms. Unlike a gas, the atoms in a liquid are usually much closer together because liquids usually have a much higher density than gases do. Because there are more of these atoms in a space, the atoms more often get close to each other. This means that the tiny forces the atoms exert have more of a chance to affect the other atoms around it. This helps hold the liquid together.

For example, think of dripping water on a window. The water forms into little droplets. This is because the liquid pulls on itself and forms little balls. If there were no forces between the atoms, the liquid would spread out forever.

On earth, a characteristic of a liquid is that it will take the shape of whatever container it is in. This is because gravity pulls the liquid towards the ground, and the atoms of the liquid can slide past each other until they form whatever shape they are in.

Solid:

A solid is another phase of matter. Again made of atoms, solids are generally much more closely packed than liquids are. This means that solids usually have a higher density than liquids. The atoms in a solid are arranged in a certain way. Because they are so close together all the time, the tiny forces each atom puts on other atoms around it hold all the atoms together. This makes them stronger. This is also why a solid does not usually take the shape of what it is in.

For example, think of a brick. A brick is a solid. It will not just sink to the bottom of a cup and take the cups shape like a liquid would. Think of it this way. Pretend a liquid is handful of marbles and a solid is a stack of legos. The legos are stacked together to build a block or a house or something else. The marbles do not attach to each other. Because of this the marbles can slip past each other but the legos will not. If you put the marbles in a cup, they will roll to the bottom and fit the cups shape. The legos will not.

The atoms in a solid come together and hold on to each other tightly. This hold is called a bond. Some bonds can be stronger than others. Usually, when the bonds of a solid are really strong it makes the solid really strong. When the bonds of the solid are very weak, the solid is very week. Think about trying to break a brick and a piece of wood. Sometimes a person can break a piece of wood with their hands. But that person could probably not break the brick with their hands. This is because the bonds holding the brick together are stronger than the ones holding the wood together.

Changing Between Phases:

Changing from one phase to another can usually be accomplished two ways. For now, consider heating something up. If someone leaves an ice cup in the sun, it will turn into water. If someone leaves water in the freezer, it will turn into ice. If someone leaves, water on the stove, it will boil and turn into water vapor which is a gas. The whole time, the water is always there. It is just in different phases. So remember, in general if you heat up a solid, it will turn to liquid, and if you heat up a liquid, it will turn to gas.

Summary of Properties:

The phases of matter usually follow these characteristics:

Property	*Solid*	*Liquid*	*Gas*
Density	High	Middle	Low
Will affect other atoms	Strongly	Moderately	Weakly
Heat up to make	Liquid	Gas	Hotter Gas

A.1.6 Energy

6. Energy

Definitions:

Energy: The ability to do work.
Kinetic Energy: The energy that a moving object has.
Potential Energy: Stored up energy that can be released.
Vibration: Moving back and forth repeatedly.
Heat Energy: The energy that comes from particles vibrating.
Temperature: How hot or cold something is.
Chemical Energy: The energy that is stored in the bonds in something.
Conversion: Changing one thing into another thing.
Conservation of Energy: The total energy in the world is always the same.

Energy:

Energy is the ability to do work. That means that energy can cause a change in something else. It can change many different things. Energy can change where an object is, how it is moving, what it feels like, and even what it looks like. Energy seems different than matter because energy is not something that a person can grab and often not even see. There are many types of energy. For example, think about running. If a person goes running, they use up energy in order to get themselves moving. When they run out of energy they get tired. Energy can come in many different types like kinetic energy, potential energy, heat energy, chemical energy, sound energy, and light energy. Four types will be discussed in detail.

Kinetic Energy:

Kinetic energy is the energy that a moving object has. That means that if something is moving, it has kinetic energy. Think about a football. If a football is sitting perfectly still, then it has no kinetic energy. But if a kid picks it up and throws it, the ball is moving, and now it has kinetic energy. Anything that can move can have kinetic energy, and the faster it moves, the more kinetic energy it has. The Earth has kinetic energy because it is moving around the sun. A person can have kinetic energy when they run or walk. Water can have kinetic energy when it is flowing in a river. Remember, when something is moving, it has kinetic energy. The faster an object moves, the more kinetic energy it has.

Potential Energy:

Potential energy is stored up energy that can be released. Different things can store potential energy. Think about a spring. If someone pushes on a spring the spring wants to pop back. When the spring pops back, it has kinetic energy because it is moving. But when the person initial pushes on the spring, that person gives the spring potential energy. It is stored up energy that is released when the person stops pushing on the spring. Think of another example. Pretend a person is holding a ball in the air. The ball is not moving when they hold it, but if they let go, it would fall to the ground. Gravity pulls it to the ground. But when it is moving it has kinetic energy. When it is being held above the ground it has energy stored into it that is released when it is let go. This kind of potential energy is caused by gravity.

Heat Energy:

Heat energy is the energy that comes from particles vibrating. Vibrating just means to move back and forth repeatedly. That means that heat is just the energy from all of the atoms in a phase of matter (look back at topic 5) that exists because those atoms move back and forth over and over again.

The faster the particles vibrate, the more heat energy they have. Each particle moving has its own kinetic energy. Remember kinetic energy is the energy that a moving object has. A particle moving is no different. So if two particles are moving, together they have more kinetic energy than either of them does by itself. So if heat is how much kinetic energy all the particles in something has, then two things can be found out. First, the faster the particles move, the more heat energy something has because the particles have more kinetic energy. Second, if the particles in two different things are moving at the same speed, but one of the objects has a lot more particles, then the total kinetic energy of the thing with more particles is going to be higher. If the total kinetic energy of the vibrating particles is higher, then the heat energy is higher.

Temperature is different than heat energy. Temperature says how hot or cold something is. All the particles in a thing do not vibrate at the same speed. Some move a little faster, and others move a little slower. Temperature just says how fast the particles in the middle are moving. It is different than heat energy because heat energy is the total energy from the motion of all of the particles.

Think about the difference like this. An iceberg is very cold. Its temperature is very low. A cup of boiling water is very hot. Its temperature is very high. This is because the particles in the iceberg are not moving very fast. The particles in the boiling water are. But the iceberg is huge compared to the cup of boiling water. It has so many particles that adding up the little amount of energy from each particle makes a lot of energy in the end. The cup of boiling water has so few particles that the particles adding up the higher energy of each particle does not make as much energy as adding up the little bits of energy from the huge amount of particles in the iceberg. So the iceberg has a lower temperature but higher heat energy than the cup of boiling water.

Chemical Energy:

Chemical energy is the energy that is stored in the bonds in something. Remember that bonds can exist between different atoms and particles. These bonds hold energy. This means that something that is made up of many atoms bonded together can hold a lot of energy. When the bonds are broken, the energy in them is released.

For example, think about food. Food is a thing made up of many atoms. These atoms are bonded together. That is why food has a lot of energy. If a person looks at the back of a juice bottle or a box of food and see the nutrition facts list, there is usually one line that says the number of calories in one serving of that food or drink. The number of calories tells you how much energy is in that serving of food. If the calories are higher, there is more energy in it.

Fuels like the gasoline in a car, the propane in a barbeque, or the denatured alcohol in the Sterling engines all have energy stored in the bonds inside them. When these things are burned, the bonds break apart and release the energy.

Think about one more example. A person pours water into a cup. The cup of water is at room temperature, so it is not too hot and not too cold. Remember talking about heat energy. This means that the particles in the water are moving but they are not moving very fast or very slow. Remember talking about the phases of matter. When the person puts the cup of water into the freezer, the molecules bonds start to form and get stronger. That means that the frozen water, or ice, has more chemical energy than the liquid water. Now the person takes the cup out of the freezer and puts the ice on the stove. The ice melts, and then the water boils. Now the water is a gas called water vapor. This gas has very few bonds that are very weak. So the gas has less chemical energy than the liquid water or the ice.

Remember chemical energy is the energy stored in the bonds of something. Foods, drinks, and fuels are good examples of things with a lot of chemical energy.

Conversion and Conservation of Energy:

Scientists in the past came to realize a few very important things about energy. First, they realized that the amount of energy in the universe must always be the same. They called this the *Conservation of Energy* because to conserve means to save. This means that no energy is created or destroyed. But conservation of energy can also relate to smaller things than the universe.

Second, scientists realized that energy can move from one thing to another. For example, if a ball is rolling and has kinetic energy and then runs into another ball, then that second ball will begin to move, but the first ball will slow down. This means that some of the kinetic energy from the first ball went into the second ball. The total amount of energy was the same after the two balls hit, but now each ball had some energy instead of the first ball having all of it.

Remember when the two balls hit, they had a collision.

Third, scientists realized that one kind of energy could be changed, or converted, into another kind of energy. This was a very important discovery. This means that one kind of energy can become another. When scientists think about conversion of energy sometimes they say that the energy in a situation has to be conserved as well. The thing that they are talking about might be a lot smaller than the universe, but many times, saying that the energy converted is also conserved is almost completely true.

For example, when a person lifts a ball into the air, the ball gains potential energy because of gravity. When the ball falls, it starts moving, so it has kinetic energy. The conservation of energy says that the amount of energy in the universe always has to be the same. Remember that means that no energy can be created or destroyed. So the kinetic energy the ball now has had to come from somewhere. In fact, the kinetic energy came from the stored up potential energy of the ball. When it was in the air, the ball had potential energy. When the ball fell, the potential energy turned into kinetic energy as the ball started moving. Think about the opposite. What if a person throws a ball straight up into the air? The ball will move up quickly and then stop before it begins to fall. When it stops moving, the ball has no kinetic energy. But since it is off the ground in the air, it has to have potential. So the kinetic energy the ball had becomes potential energy, and when the ball begins to fall again, the potential energy turns back into kinetic energy.

Think of another example. When a fire lantern is burning, the chemical energy in the bonds of the fuel is being converted to heat energy and light energy. The bonds in the fuel are breaking apart as the fuel burns, and the energy that was in those bonds is turning into heat energy and light energy.

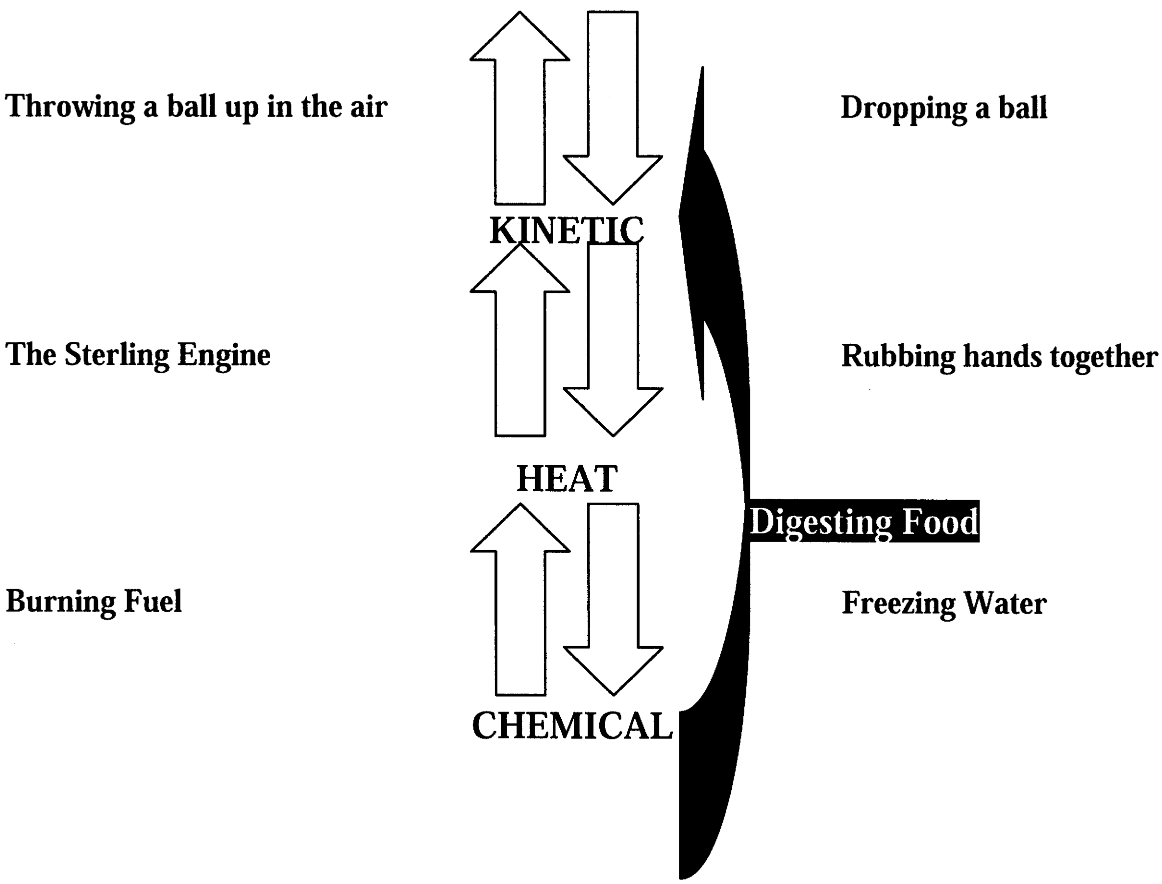
Another example goes back to talking about the cup of water being frozen and boiled. When the cup is frozen, the particles begin to move slower. Remember this means that not only the kinetic energy of the particles but the heat energy of the whole cup of water is less. Where does all of this energy go? The answer is that it goes into the bonds that are formed between the particles in the ice. The ice is a solid so it forms a lot of bonds. These bonds hold the energy that used to be heat. When the bonds are broken, the energy is released again and moves the particles around until it becomes slightly warmer liquid water.

One more example is converting kinetic energy into heat energy. If a person rubs his or her hands together, the kinetic energy that the person's hands have generate heat energy. This is why the person's hands feel warmer after rubbing them together. Try to follow this from start to finish. A person goes and eats some food. That food has kinetic energy. The person's body breaks down the food to release the energy that the person uses to move their hands. When the hands rub together, heat is generated. This example shows how chemical energy becomes kinetic energy which becomes heat energy.

These are a bunch of examples that show how one type of energy can become another type. The most important example of them all is how to go from heat energy to kinetic energy. The thing that people use to do that is called an engine. The engine in a car burns fuel that releases chemical energy into heat energy that then makes the car move. This will be explained in more detail later. What is important is that engines take heat energy and convert it into kinetic. The Sterling engine is an example of a machine that does this.

A Few Examples of Converting Energy:

POTENTIAL



A.1.7 Pressure

7. Pressure

Definitions:

Pressure: The ratio of force to area.

Pressure:

Pressure is the ratio of force to area. Remember that a ratio is the amount of one thing compared to the amount of another thing. So pressure is how much force there is on some amount of area. So if there is a lot of force in a small area, there is a lot of pressure. If there is little force in a big area, there is low pressure. Remember that if something puts force on something else, they will always put pressure on that other thing. Also, when something puts pressure on something else, it always puts a force on that other thing.

Imagine a brick that is much longer than its height or width. The brick is lying on a table. No matter which way the brick is lying, it will always weigh the same. So the force the brick puts on the table because of gravity will not change if the brick is turned over or put up on one side. But the pressure that the brick will put on the table does change depending on how it is laying. The different sides of the brick have different areas. Remember the area is how much space something takes up on a surface. Think about the brick lying down on a side that has a lot of area. The pressure will be low because the force is the same all the time and the area is large. If the brick is stood up on one side so that it stands on a side with a small area, the pressure will be high because the force is the same all the time and the area is small. Because the area can change, the pressure can change.

Pressure can change in another way. If the area always stays the same but the force can change, then the area can change. A person can feel this different in pressure easily. If a person puts one hand on a table and pushes down lightly, he or she will feel some pressure on his or her hand. By pushing harder, the person increases the force but does not change the area because his or her hand does not change size. So the pressure the person is putting on the table goes up. So because the force can change, the pressure can change.

All of the phases of matter can exert pressure. Remember the differences in solid, liquid, and gas. Those are three phases of matter. Remember that, in general, a solid has a higher density than a liquid which has a higher density than a gas. This is very important. Imagine some amount of matter. Imagine this matter is in a solid. If the matter then becomes a liquid and then has a lower density, it will have to take up more room if there is nothing stopping it from getting larger. Then if that liquid became a gas, it would have a lower density and would have to take up more room if nothing was stopping it from getting bigger

So remember that each phase of matter can exert pressure, and the atoms in each phase exert this pressure by putting a force on something. So in a solid the atoms are linked together with strong bonds. In a liquid, the bonds are weaker and the atoms are freer to move. In a gas the bonds are very weak and the atoms can move around almost independently. Although the atoms push and pull on each other differently, when they put force on other things, they apply a certain pressure.

A solid can put pressure on something in a lot of different ways. Leaving a brick on a table will put force on the table because of the bricks weight. If a person picks up a brick and pushes on a wall, the force from the person's hand goes through the brick, and the brick puts pressure on the wall. The person can also throw the brick, and when it hits the wall, the force the brick puts on the wall will also exert a pressure.

A liquid tends to go to the bottom of whatever container it is in. In this position, the weight of the water puts pressure on the walls and bottom of the thing it is in and also anything that might be inside the water. Think about being in a pool. If a person dives to the bottom, there is a lot more water above him or her, and the weight of that water pushes down on that person. This means that the pressure on a person is higher the deeper they dive. This is why that person's ears will begin to hurt in deep water. Force can also go through water. Just like a person who pushes on a wall with a brick, someone can push on a wall with a balloon full of water. The force still goes through the water to the wall. Also, throwing water, like when it comes out of a hose, can put pressure on something. When the water hits something, it puts force on that thing. This is why a person can push a ball or something else with a hose that shoots water fast.

A gas tends to fill up whatever it is inside of. So a gas will put pressure on all of the walls, top, and bottom of whatever it is in. Again, force can go throw a gas. If a person pushes on a wall with a regular balloon filled with air, the force will still go through the gas to the wall. A gas can also be blown against something like when a person blows hard from their mouth or when the wind blows. This moving gas can put a pressure on whatever it runs into.

Think about one example. Remember that a gas usually takes up more room than a liquid. Pretend that someone name Will puts some liquid into a balloon that fills up the balloon completely. Then Will somehow makes that liquid turn into a gas. If the gas takes up more room than the liquid, then the balloon will have to get bigger. This can happen because the walls of a balloon can stretch to make room for the gas. What if the same thing happened but inside a closed soda can. The walls of this can cannot stretch very much, so the gas is going to push really hard on the walls of the can, and if the can cannot hold the gas in, it will explode. If the can holds the gas in, the gas will continue to push really hard until it gets out. Imagine that when the liquid turns to gas there is a hole in that can. Now the gas has somewhere to go. So the gas will push out of that whole because it wants to get bigger.

This example relates to an important point about pressure. Imagine a wall with a hole in it. If there is matter than can get through the hole and the pressure on one side of the whole is larger than on the other, some of the matter will push its way through that hole to get to the other side.

Remember three important things that were said. First, pressure is the ratio of force to area. Second, in general a gas will want to take up more room than a liquid which will want to take up more room than a solid even if all three have the same amount of matter. Third, gas, liquids, and solids can all exert pressure.

A.1.8 Friction

8. Friction

Definitions:

Surface:	The boundary of an object.
Fluid:	A liquid or a gas.
Friction:	The force that tries to stop motion between the surface of an object and the matter is in contact with.
Kinetic Friction:	The force that goes against an object's motion when a surface of that object is in contact with some other matter that is moving faster or slower than it.
Sliding Friction:	The type of kinetic friction that exists between two solid surfaces.
Fluid Friction:	The type of kinetic friction that exists between a solid surface and a fluid and is sometimes called drag.
Lubricant:	A substance placed in contact with a surface that makes the force of friction on that surface smaller.

Friction:

Friction is the force that tries to stop the motion between the surface of an object and the matter it is in contact with. Remember that a force is a push or a pull. This means that friction is a push or a pull on an object that changes its motion. Many different things change how much force there is. One very important thing is the type of matter on the surface of the object and the type of matter that surface is in contact with. For example, if a person pushes two pieces of ice together and tries to move them, they move much easier than if the person pushed two pieces of sandpaper together and tried to move them. There are many types of friction, but in general, friction converts other types of energy into heat energy. Kinetic friction will be discussed in detail.

Kinetic Friction:

Kinetic friction is the force that goes against an object's motion when a surface of that object is in contact with some other matter and is moving faster or slower than that other matter. Remember that a force is a push or a pull that changes the motion of an object. A person might wonder why his or her car slows down when then let go of the gas even if the car is on a flat road or why something sliding on a table will slow down if it is not pushed or pulled the whole time. The reason is that there is something that is causing that thing to slow down. If an object is moving and then starts to slow down, its motion has changed. The object must have had a force put on it. The force that opposes the motion of an object because that object is in contact with other matter is called friction. In both the example of the car slowing down and an object sliding on a table, surfaces of the object are moving faster or slower than the matter they are in contact with. This contact is creating a frictional force that is going against the motion of those objects.

Some of the kinetic energy that they had is converted into heat energy. Remember heat energy is the energy from the vibration of particles in something. Imagine a person running a hand over guitar strings. As their hand moves by, the strings begin to vibrate because there was a force put on them by the hand. In the same way, imagine running a finger over a toothbrush head. As the finger moves by, the bristles, which are the little pointy threads, on the toothbrush begin to vibrate for a second. Just like these two examples, when one surface moves past the other matter, the force between them causes the particles to vibrate more. This takes some of the kinetic energy away from the moving object and the matter and turns it into heat energy.

Remember the first two examples about the car and something sliding on a table. Both things slow down because as the friction acts on the object, some of its kinetic energy is turned into heat energy until it has no more kinetic energy left. At this point, the objects stop. Think about one more example. Imagine some children are sliding down a slide. Right after sliding down the slide, if they stand up and check whatever part of their body they were sliding on, they will feel that that part is a little warmer than it used to be. This is because part of their kinetic energy was turned into heat energy.

There are two types of kinetic friction, and both have already been discussed.

- Sliding Friction: This is the friction between two surfaces in contact while one is moving faster or slower than the other. This is like an object sliding on a table. Imagine a book slid across a table. The bottom of the book is moving faster than the surface of the table. The table puts the force of friction against the book and slows it down. The kinetic energy of the book becomes heat energy.
- Fluid Friction: This is the friction between a surface and a fluid. A fluid is just a liquid or a gas. When the surface moves through the fluid, it rubs against the particles in the fluid and loses some of its kinetic energy by vibrating those particles faster. Again, this means that the kinetic energy became heat energy. Imagine a person standing still. That person can tell that the wind is not blowing. If he or she starts running, he or she will feel wind in their face. This is because the surface of that person's skin is moving past the air molecules. This creates a force of friction that can be felt. This is sometimes called drag.

Remember there are two types of kinetic friction, but both cause kinetic energy to become heat energy, and both happen when the surface of a on object is moving faster or slower than other matter that it is touching.

Lubricants:

Lubricants are substances which are put on a surface to make the force of friction on that surface smaller. Imagine someone rubbing the skin on an arm with the other hand. If that person then puts sunscreen in his or her hand and then rubs the same arm, his or her hand will slide back and forth much more easily. Many lubricants feel slippery to the touch. People often talk about putting oil in a car or changing the oil in the car. Oil is a type of lubricant. It is used in the engine of a car to lower the friction between surfaces inside the engine. Without it, the engine would not function properly. With more friction, it would become very hot and probably break. There are many different kinds of lubricants that are used in many different situations.

A.1.9 Gases

9. Gases

Definitions:

Gas:	The phase of matter in which the atoms are most spread apart and are almost completely free to move without being affected by the atoms around it. Gases generally have low densities.
Constant:	Not changing
Law:	A rule that nature has to follow.
Expand:	To get bigger.
Contract:	To get smaller.
Boyle's Law:	When the temperature and mass of a gas are constant, the pressure goes up when the volume goes down, and the pressure goes down when the volume goes up.
Charles' Law:	When the pressure and mass of a gas are constant, the volume goes up when the temperature goes up, and the volume goes down when the temperature goes down.
Gay-Lussac's Law:	When the volume and mass of a gas are constant, the pressure goes up when the temperature goes up, and the pressure goes down when the temperature goes down.
Ideal Gas:	A gas that follows Boyle's Law, Charles's Law, Gay-Lussac's Law, and one other law. An ideal gas follows the Ideal Gas Law which is all four of those laws put together.

Gases:

The above definition of a gas was copied from topic 5, *Phases of Matter*. For a description of a gas refer to topic 5. Remember the atoms in a gas are flowing around almost freely in whatever space they take up. The space that the atoms of a gas take up is called the volume of the gas. Gases put pressure on the things they touch. Remember pressure is the ratio of force to area. So the pressure a gas puts on the things it touches is how much force the gas puts on the things for the amount of area it is touching. Remember the area is the amount of space of something on a surface and that constant means not changing. Also, remember that the temperature of something is how hot or cold it is. Not all the atoms in a gas will have the same kinetic energy because not all the atoms in a gas will be vibrating at the same speed. Temperature is related to the kinetic energy of the atoms moving at a middle speed. Heat energy is all of the atom's kinetic energy put together. The last important term to remember is mass which is the amount of matter in something. So the mass of a gas is how much matter is in that gas.

Think about why a gas puts a pressure on things. The atoms in a gas are moving around and bounce off of each other and the surfaces of whatever it touches. When they have collisions, which is one thing running into another, they put a force on what they hit and a force is put on them. Their motion changes even if it does not change much, and so there has to be a force. Well you can imagine if there are a bunch of these little atoms in a gas and they are all hitting the surfaces of the things they touch, then in total they are putting force on that surface. How big that surface is changes the area that the force is put on. Pressure then is the ratio of force to area. It is how much force there is on a certain area. Imagine air in a balloon. The air in the balloon is running into the walls of the balloon. The force put on the walls of the balloon from the air inside is what keeps the walls of the balloon out. Remember there is air on the outside of the balloon hitting the walls as well. When the air on the inside is pushing just as hard as the air on the outside, then the balloon stops changing shape.

Volume, pressure, mass, and temperature all relate to how gases act. Many gases follow a few simple rules when they act although other gases do not. Named after old scientists, the following rules which relate to many gases are as follows. These rules are called laws because nature has to follow them. They will be explained in detail. Imagine some gas and think about the following rules.

Boyle's Law

- When the temperature and mass are constant:
    - If the volume goes up, the pressure goes down.
    - If the volume goes down, the pressure goes up.

Charles' Law

- When the pressure and mass are constant:
    - If the temperature goes up, the volume goes up.
    - If the temperature goes down, the volume goes down.

Gay-Lussac's Law

- When the volume and mass are constant:
    - If the temperature goes up, the pressure goes up.
    - If the temperature goes down, the pressure goes down.

There are rules that talk about what happens when the mass changes but those are more complicated. One example is pumping up a tire. To pump up a tire, a person forces more and more air into that tire until the tire is full. As they add more air, the volume of the tire goes up and after a certain point, the pressure in the tire also goes up. This is a much more complicated situation that may be a good thing to look up later or ask about. Remember that to expand is to get bigger and to contract is to get smaller. It is important to discuss the laws in detail.

Boyle's Law:

Boyle's law says that if the temperature and mass of a gas are constant, then if the volume goes up, the pressure goes down, and if the volume goes down, then the pressure goes up. Imagine a person holding a balloon filled with air. If the person squeezes on the balloon and tries to make it shrink, they feel a lot of pressure on their hands pushing back. This is because they walls of the balloon closer to the air inside. If a person was running back and forth between two houses, and then someone moved one of the houses closer to the other, then the person running back and forth could go back and forth more often. This is the same as the atoms in a balloon. The hit the walls of the balloon more often as the walls get closer, and so they put more force on the walls which makes a higher pressure. Also, by pushing the walls of the balloon closer, the person decreases the area on the inside of the balloon by a little. This also makes a higher pressure.

The opposite is also true. If the walls of the balloon were pulled away to make the volume bigger, the atoms would hit the walls less often, and the area of the walls would be larger. Both of these things would make a smaller pressure.

Charles' Law:

Charles' law says that if the pressure and the mass of a gas are constant, then if the temperature goes up, the volume goes up, and if the temperature goes down, then the volume goes down. Imagine a person holding that same balloon. If that person heat up that balloon in some hot water, the balloon will get bigger by just a little bit. If they cool it down in some ice water, the balloon will get smaller by just a little bit. Again, this change is because of the atoms of the gas hitting the walls of the balloon. If the temperature of the gas goes up, then most of the atoms will have a little more kinetic energy than they did before. If they have more kinetic energy, they are moving faster. Remember the person running back and forth between two houses. Imagine that they start running much faster. Now they can go back and forth between the houses more often. So the atoms in the gas start running into the walls of the balloon more often and harder. This puts a little more pressure on the walls of the balloon, but remember, the volume does not have to be the same. So because the pressure on the inside of the balloon is greater than the pressure outside, the balloon gets a little bigger until the bigger volume causes the pressure to return to what it was before. Just like in Boyle's law, when the volume went up, the pressure went back down.

The opposite is true. If the temperature of the gas goes down, the atoms slow down and put less pressure on the walls of the balloon for a moment. The pressure outside is greater than the pressure inside so the balloon shrinks, but when it shrinks, the pressure goes back to what it was before. Just like in Boyle's law, when the volume went down, the pressure went back up.

Gay-Lussac's Law:

Gay-Lussac's Law says that when the volume and mass are constant, if the temperature goes up, the pressure goes up, and if the temperature goes down the pressure goes down. This law follows similar steps as the last two. Imagine a strong coffee can that is only filled with air and sealed at the top. When the temperature goes up in the gas, the atoms move around faster and hit the walls of the can more often with more force. This makes the pressure on the walls go up. But the walls are so strong that they do not move even though the pressure on the outside is less than the pressure on the inside. This means that the volume stays constant and the pressure in the can stays higher.

Again, the opposite is true. If the temperature goes down, the atoms move around slower and hit the walls less often with less force. But the can cannot get smaller even though the pressure on the outside is higher than the pressure on the inside. So the air on the inside stays at the lower pressure.

Ideal Gases:

An ideal gas is a gas that follows the three laws above. Not all gases are ideal gasses. In fact, no gas is a perfect ideal gas. There are many gases that are so close to an ideal gas, that scientists call them ideal gasses. Ideal gasses follow the ideal gas law which is all of the three above laws put together with the law that talks about what happens when mass changes. This final law, which talks about changing mass, is called Avogadro's Law which has not been discussed but would be a good thing to look up later. All of these laws are sometimes called the gas laws.

A.1.10 Heat Transfer

10. Heat Transfer

Definitions:

Heat Transfer:	The movement of heat energy from one place to another because of a difference in temperature.
Conduction:	One kind of heat transfer where heat energy is transferred as particles vibrate against one another.
Convection:	One kind of heat transfer where heat energy is transferred because a fluid is in contact with something.
Radiation:	One kind of heat transfer where heat energy is transferred through energy waves.
Thermal Conductivity:	How easily something can transfer heat energy based on what that something is made of.
Thermal Resistance:	How hard it is to transfer heat from one point to another.

Heat Transfer:

Heat transfer is heat energy moving from one place to another. The reason the heat moves is because there is a difference in temperature between the two places. There are three different ways in which heat can be transferred. Those ways are conduction, convection, and radiation. Each are very different and apply to different situations. Examples of heat transfer are putting a marshmallow in a fire, boiling water, and leaving a drink in the sun.

Also, different things have different thermal conductivities. A thermal conductivity is just a number that says how easily heat can transfer through something based on what that something is made out of. For example, think about different metals like gold, silver, and bronze. Each of these metals is different. Based on what metal it is, the thermal conductivity will be different. Also, think about the difference between a metal and water. The thermal conductivities of those two things will also be very different. One is made of metal and the other is made of water. Remember the thermal conductivity has nothing to do with how tall or long or shiny the thing is.

A slightly similar but different idea is the thermal resistance of something. The thermal resistance is just how hard it is to transfer heat using one of the three ways, conduction, convection, and radiation. The thermal resistance of something depends on a lot of different, more complicated things. It has to do with what that something is made out of but also may depend on shape, color, or other things. For example, a tiny block of gold may have a much different thermal resistance than a much larger block of gold with a different shape. Both are made out of gold so the thermal conductivity of both blocks has to be the same because thermal conductivity only has to do with what something is made out of. But the thermal resistance of the two blocks can be different because they are different shapes and may have other differences. Think of one example of thermal resistance. A group of friends needs to try to get through a door as fast as they can. They have two choices. The first is a little door, and the second is a really large door. The friends choose the really large door because if they all tried to get through the little door at the same time they would bump into each other and get stuck. If they went through the large door they could all easily run through it without a problem. The friends are like heat energy. Depending on size, shape, and other things, heat energy has a harder or easier time getting through something. How hard it is to get through that something is that thing's thermal resistance.

Conduction:

Conduction is a type of heat transfer where heat energy is transferred as particles bump into each other. For example, if a person takes a metal spoon that is at room temperature and then puts it in a pot of boiling water, eventually the spoon will get very hot and burn the person's hand. This is because the hot water gave heat energy to the end of the spoon that was in it. This heat energy is just the atoms in the spoon vibrating. As they vibrate, they hit the atoms next to them. The first atoms vibrate a bit slower but the second atoms vibrate a bit faster. This bumping continues all the way up the spoon until the particles at the other end of the spoon bump into the person's hand. This makes the atoms in the person's hand vibrate more. So the spoon gives the person's hand heat energy. Remember that this heat energy moved because there was a difference in temperature between the end of the spoon and the person's hand. Imagine a lot of people bunched into a tiny room with only a little bit of space to move. If a person at one end starts trying to move they are going to bump into the other people who will probably bump into the people next to them and so on until the people at the other end also get moved. This is the same as the particles in any phase of matter. When water or air gets heat energy from somewhere, the heat energy can be transferred between the particles in those things as the vibrating particles bump into each other. So conduction is just a type of heat transfer where heat energy moves because vibrating particles bump into other particles and make them vibrate more.

Convection:

Convection is a type of heat transfer where heat energy is transferred because a fluid, which is a liquid or a gas, is in contact with something else. Remember the metal spoon in the boiling water example. The way that the boiling water gave the end of the spoon heat energy is through convection. There was a difference in temperature between the end of the spoon and the boiling water. The vibrating particles in the water were moving around and would sometimes run into the spoon. When they ran into the spoon, the particles in the spoon began to vibrate more. This is how the vibration, which is the heat energy, was transferred from the water to the spoon. Why does a person blow on hot chocolate to cool it down? This is because that person wants the air particles to run into the fast vibrating particles in the hot chocolate. When they particles in the hot chocolate hit the air particles, the air particles vibrate faster but the particles in the hot chocolate vibrate slower because they gave up some of their energy. This transfer of heat energy when the particles in a fluid run into something else and make the particles in that other thing vibrate more is called convection.

Radiation:

Radiation is a type of heat transfer where the heat energy is transferred through energy waves. For example, the sun is really far away but still heats up the earth. This is because the sun sends out light rays and other rays that are waves of energy. When these rays run into the atoms in something, the rays give those atoms energy and make them vibrate faster. If something is next to the sun, it would be very hot. But it would take a long time for the sun to heat up particles and have those bump other particles until they got to the earth because space has very few particles in it. It is almost empty. But the speed of light is very fast. These energy waves travel at the speed of light. This explains how the sun can heat up the earth even though it is very far away. This is also the reason that people try to get in the shade to cool off if they are outside. The suns rays do not hit a person in the shade as much as they do when the sun is directly on the person. So radiation is a type of heat transfer where heat energy moves through energy waves from one place to another.

A.1.11 The Stirling Engine

11. The Stirling Engine

Definitions:

Cycle:	Something that repeats over and over again.
The Stirling Engine:	A type of engine that runs from a heat source outside, traps only air inside, and goes through the Stirling Cycle.
The Stirling Cycle:	The cycle that the Stirling Engine goes through when it moves.

The Stirling Engine:

The Stirling Engine is an engine which goes through the Stirling Cycle as it moves. The Stirling Engine has only air inside of it and runs from a source of heat that is outside of it. The Stirling Cycle describes how the engine operates. It has four steps: expansion, transfer of air from the hot side to the cold side, contraction, and transfer of air from the cold side to the hot side. There are a few very important pieces of the Stirling Engine that make the engine work. There are two cylinders and two pistons. One set is called the displacer piston and cylinder and the other is called the power piston and cylinder. To displace just means to move something to another spot. The displacer piston moves the air from one side of the engine to the other. The power piston is where the actually turning of the engine starts. It is called the power piston because this is where the engine gets its power. There is some room between the displacer piston and the displacer cylinder for air to move through. There is not room between the power piston and power cylinder. It is such a tight fit and air cannot move between the piston and the cylinder. Also, remember that the two pistons are connected by a small hole.

The displacer piston works in a simple way. When it moves through the displacer cylinder that is filled with air, the air moves to the side where the displacer piston is not. Imagine a bunch of small children standing in a narrow hallway. Also, picture a large wrestler coming down the hall way trying to get to the other side. If the children stand in the wrestler's way, they will be pushed to the end of the hallway until there is not enough room for them all on one side of the wrestler. Then, one by one, they will begin to squeeze past the wrestler between him and the wall until the wrestler gets where he or she is going. This would happen if the wrestler was moving down the hall one way or the other. This is like the air in the displacer cylinder. The displacer piston moves down the cylinder and all of the air is pushed until there is not more room for it. Then, the air only has the choice of sliding around the displacer piston to the side of the cylinder where the displacer piston is not in. This also works if the displacer piston is moving the other way.

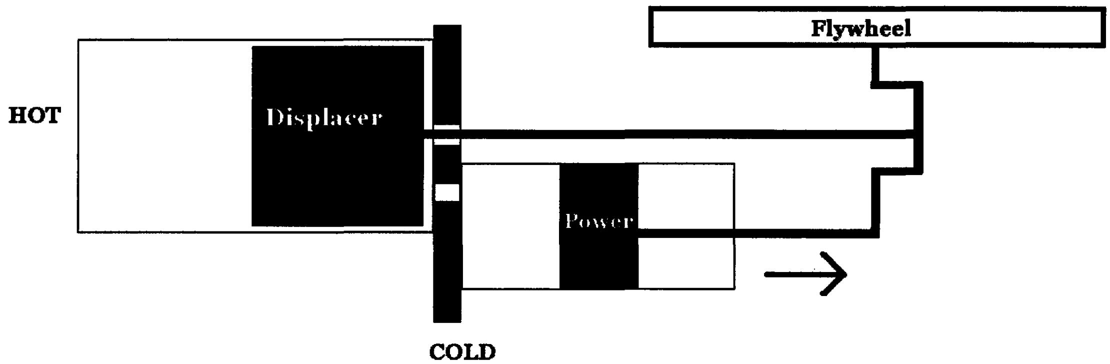
The power piston works differently. Remember one end is open to the air outside. At different times, the changes in temperature inside the engine make the air expand or contract. When the air expands, it eventually pushes again the power piston. Because it cannot get by the power piston, it has to push the power piston out to make more room for itself. When the air contracts it does the opposite. As it shrinks, it does not push on the power piston as hard so the air outside can push the power piston back in. Moving the power piston back and forth causes the flywheel to spin.

Think back to inertia. Inertia was the property of matter that said something will try to stay in the motion that it is in unless an outside force tries to change its motion. Think of a bicycle wheel. If a person spins a bicycle wheel, it does not stop immediately. Eventually, friction provides enough force to stop the wheel. Friction will do the same for the flywheel on the Stirling Engine. But the flywheel is there because it has inertia. Imagine a person driving in a car. If he or she only pushed on the gas a little bit over and over again, the ride would be pretty bumpy. If he or she pushed on it slowly until the car reached the right speed, the ride would be smooth. The flywheel only moves when the power piston is moving. But the power piston moves back and forth which means at some point, it must stop and turn around at one end and at the other. When it stops to turn around, nothing is pushing the flywheel. If the flywheel was not there, the engine would run very jerkily, spinning the flywheel axel suddenly, waiting, and then doing it again. This would be bumpy just as if the person driving in the car pressed on the gas pedal over and over again but never kept his or her foot on it for long. The flywheel changes this. When the power piston spins the flywheel, the inertia of the flywheel makes it so it does not want to stop really fast. Again, remember that if someone spins a bike wheel, it will not stop quickly but will keep spinning until friction finally stops it. This is the same with the flywheel. The flywheel keeps spinning even when the power piston is not pushing it. This makes the engine running very smooth just as if a person slowly pressed on the gas pedal in a car until it got to the right speed. By the way, the reason the flywheel must be spun to get the engine to start in the first place is also because the flywheel has inertia. It is sitting still so it does not want to move when the flame is first lit. Spinning the flywheel helps the engine get past the inertia.

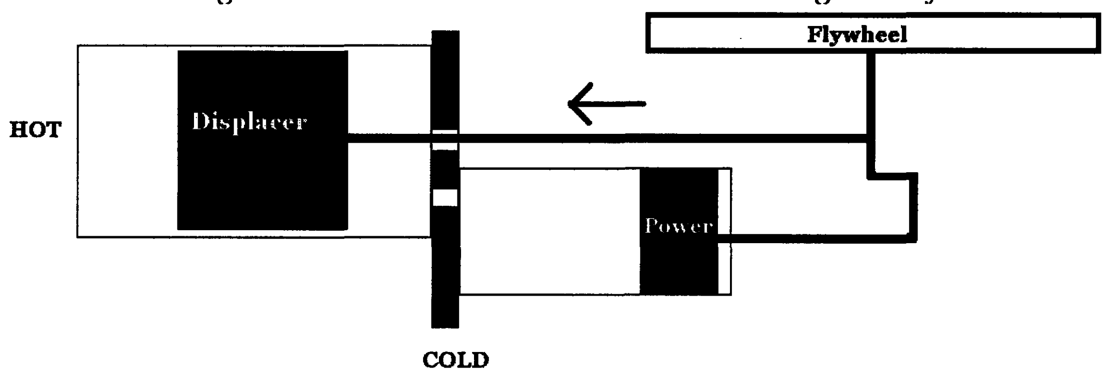
These are the three most important parts of the engine to understand before trying to understand the cycle. The last important thing to notice is all of the links that connect the flywheel to the two pistons. These links are set up in a way to keep one piston moving in the right direction when the other is moving one way or the other. Without these links set up just the way they are, the engine would not work well. Remember, the flame is heating the engine the entire time it runs making one side of the engine very hot while the other side stays about the same temperature making it cold compared to the hot side. Also, remember, the Stirling Cycle has four steps: expansion, transfer of air from the hot side to the cold side, contraction, and transfer of air from the cold to the hot side.

The Stirling Cycle:

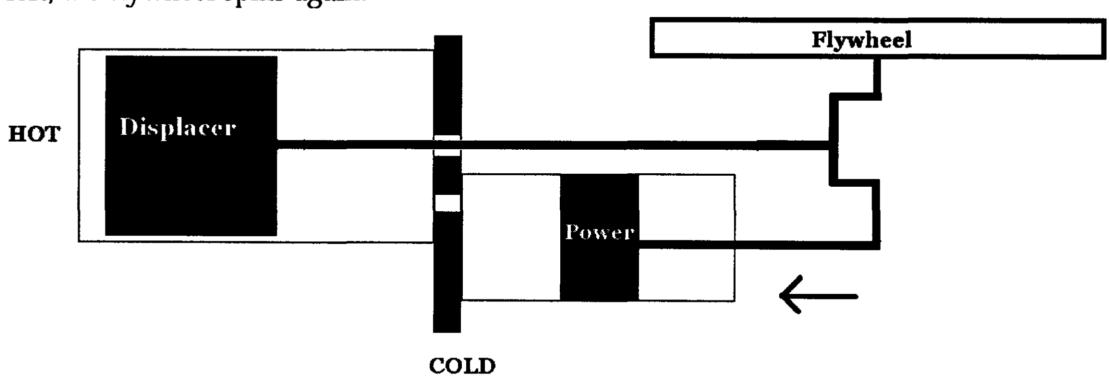
I. Expansion: Expansion is the first step in the Stirling Cycle. The flame is heating the hot side of the engine. This transfers heat from the flame to the air through the three way heat transfers, conduction, convection, and radiation. The air inside the displacer cylinder gets hot and expands. When it expands, it pushes through the hole connecting the two pistons and then pushes the power piston to the right. When the power piston moves to the right, it turns the flywheel.



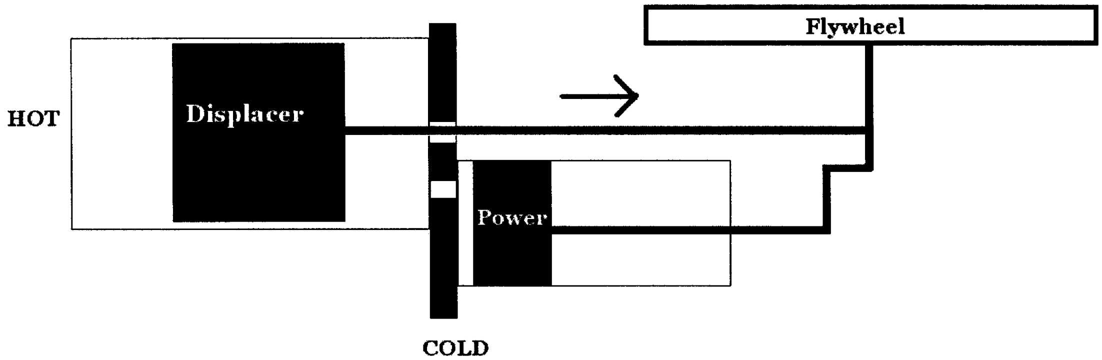
II. Transfer of Air from the Hot Side to the Cold Side: This is the second step in the Stirling Cycle. When the power piston moves outward during the expansion step, the links that connect the two pistons cause the displace piston to move to the left. If the displacer piston moves to the left, the air has to squeeze around it and move to the right. So the air goes from the hot side of the engine where the flame is to the cold side of the engine away from the flame.



III. Contraction: Contraction is the third step of the Stirling Cycle: When the air is on the cold side of the engine, it gives off heat that escapes from the engine through the three ways that heat is transferred. When the air gives of this heat, it gets colder and shrinks. When it shrinks, it does not push on the power piston as hard as it did before so the air outside of the engine pushes the power piston back inward, to the left. When the power piston moves to the left, the flywheel spins again.



IV. Transfer of Air from the Cold Side to the Hot Side: This is the fourth and final step of the Stirling Cycle. When the power piston moves back inward to the left, the links that connect the two pistons cause the displacer piston to move back to the right. Again, the air goes to where the displacer piston is not so as the displacer piston moves right, the air squeezes around it to the left, which is the hot side. This is the last step of the cycle, and when it is complete, the Stirling Cycle can repeat making the engine run.



Final Reminders:

- Use only the provided alcohol burner heat source and denatured alcohol as fuel.
- Never lubricate the power piston. This will cause the engine to stop working.
- Never touch the engine when it is running. Let it stop and cool before touching it.
- Run the engine in a well ventilated area, away from all flammable materials
- Never fill alcohol burner while it is hot, and never leave engine running unattended.
- Never store the engine with alcohol in it. Keep engine in a dry place to prevent rust.

A.2 Experiments

A.2.1 Weight and Density

Experiment 1: Weight and Density

Instructions:

This experiment will be done with groups of three. At each station, you should find a balance and a small bucket. The small bucket has little marks on it that tell you how much water is in the bucket. There should also be little weights next to the object as well.

Take each of the little buckets and put water in it until you reach a line that you can easily read. Write down this number. Then put the object in the bucket, and write down the new level of the water. The difference between the two numbers is the volume of the object.

Then use the balance to find out the mass of the objects. Put the object in one of the bowls. Then put the weights into the other bowl until the two bowls are nearly balanced. The amount of weight in the second bucket will tell you the weight of the object. If you know the weight of the object, you can determine its mass.

Knowing the mass and volume of each object, you can determine the density. This is an easy way to figure out the density of an object that you don't know.

Your Turn:

Question:

Hypothesis:

Experiment:

Water in Bucket without Object: a)__________ b)__________ c)__________ d)__________

Water in Bucket with Object: a)__________ b)__________ c)__________ d)__________

Weights in the other bowl: a)__________ b)__________ c)__________ d)__________

Volume of Object: a)__________ b)__________ c)__________ d)__________

Mass of Object: a)__________ b)__________ c)__________ d)__________

Density of Object: a)__________ b)__________ c)__________ d)__________

Conclusion:

A.2.2 Conservation of Energy

Experiment 2: Conservation of Energy

Instructions:

This experiment will show you the conversion between kinetic and potential energy. Each group has a ramp in front of them. Remember before when we discussed the conversion of energy. This experiment will help you figure out something about energy. The ramp has a few marks on it that read 1, 2, and 3. Your group should put your ball at number 1 and let it go. After it stops you should measure how far the ball went from the spot it says to measure from. Repeat this for 2 and 3. Write down the distances each time. After you write down all of this, we will talk about what it means. Make sure you fill out the question and the hypothesis before you start the experiment. Remember that the ball has kinetic energy when it is rolling and potential energy when you are about to let it go on the ramp.

Your Turn:

Question:

Hypothesis:

Experiment:

Distance Traveled when released from 1: __________

Distance Traveled when released from 2: __________

Distance Traveled when released from 3: __________

Which number (height) let the ball roll the greatest distance?: __________

Which number (height) let the ball roll the middle distance?: __________

Which number (height) let the ball roll the least distance?: __________

Conclusion:

A.2.3 Kinetic Friction

Experiment 3: Kinetic Friction

Instructions:

This experiment will show how different materials affect friction. This experiment deals with kinetic friction, and more specifically, sliding friction. Each group should have three members. Each group should have a stop watch and a block with a string attached to it that is tied to a weight. One side of that block is covered with sandpaper and the rest of the sides are just wood. There will be a paper lane for the block to slide on to make sure the tables do not get scratched. This lane should have a start line and a finish line marked about 28 inches apart. Each group should hang the weight right off the end of the table so that the string is going straight down the lane. One person should hold the block, the second should hold the stop watch, and the third should say when to start and stop. When start is called, the first person should let go of the block at the starting line and the second person should start the stop watch.

When the block crosses the finish line, stop should be called. The person with the stop watch should stop then. Make sure you rotate to allow each group member to do each job. If for some reason the block does not begin to move when you let it go, give it a very small tap to get it moving. Letting the block slide should be done three times on the wood side and three times on the sandpaper side. Each time it is done, the time should be taken and written down. Remember to fill out the question and hypothesis before you begin.

Your Turn:

Question:

Hypothesis:

Experiment:

Time the block took to move from start to finish on the wood side: try #1: ________ try #2: ________ try #3: ________

Time the block took to move from start to finish on the sandpaper side: try #1: ________ try #2: ________ try #3: ________

Conclusion:

A.2.4 Gas Laws

Experiment 3: Kinetic Friction

Instructions:

This experiment will show how different materials affect friction. This experiment deals with kinetic friction, and more specifically, sliding friction. Each group should have three members. Each group should have a stop watch and a block with a string attached to it that is tied to a weight. One side of that block is covered with sandpaper and the rest of the sides are just wood. There will be a paper lane for the block to slide on to make sure the tables do not get scratched. This lane should have a start line and a finish line marked about 28 inches apart. Each group should hang the weight right off the end of the table so that the string is going straight down the lane. One person should hold the block, the second should hold the stop watch, and the third should say when to start and stop. When start is called, the first person should let go of the block at the starting line and the second person should start the stop watch. When the block crosses the finish line, stop should be called. The person with the stop watch should stop then. Make sure you rotate to allow each group member to do each job. If for some reason the block does not begin to move when you let it go, give it a very small tap to get it moving. Letting the block slide should be done three times on the wood side and three times on the sandpaper side. Each time it is done, the time should be taken and written down. Remember to fill out the question and hypothesis before you begin.

Your Turn:

Question:

Hypothesis:

Experiment:

Time the block took to move from start to finish on the wood side: try #1: __________ try #2: __________ try #3: __________

Time the block took to move from start to finish on the sandpaper side: try #1: __________ try #2: __________ try #3: __________

Conclusion:

A.2.5 Heat Transfer

Experiment 5: Heat Transfer

Instructions:

This experiment will teach you about heat transfer. We are using hotplates in this experiment so you have to be very careful not to touch the experiment. The parents and helpers will be handling everything. I want you to observe and try to understand what is happening. On top of the hotplate, there is a circular plate of aluminum. This plate has two containers on it. One is made of aluminum and the other is made of ceramic. This means that the two different containers are made out of a different material. Remember what I said during the lecture about thermal conductivity when you are watching the experiment. The two containers are almost the same shape, so the shape should not make a big difference in the experiment. If that is true, then the thermal resistance of each container should only be different because one is made of aluminum and the other is made of ceramic. After turning the hot plate on, an ice cube will be placed in each container. Observe how the ice melts and which melts first. Try to figure out where the heat energy is moving to if it starts in the hotplate. Record your observations in the experiment section. As always, answer the question and hypothesis portions before you begin the experiment. Afterwards, we will talk about what happened and discuss the conclusion.

Your Turn:

Question:

Hypothesis:

Experiment:

Which ice cube melted first?

Conclusion: