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Design of an Eighth Grade Science Curriculum

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Abstract

The objective of this project was to develop an addendum to the regular science curriculum that would stimulate student interest. To develop this supplement, surveys were used to determine the areas of student interest. A unit focusing on electricity was then developed, including lab activities and demonstrations. With the basic lesson plans established, an iterative system of teaching and evaluation was used to refine the teaching program. Despite the more demanding material, student participation and interest in science increased.

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Trends and Theories for Improving Education

> "They did really well for people who aren't planning on being teachers."

The ability to pass knowledge from one generation to another is an important aspect of the human being. It was this ability that has lead mankind out of the woods and onto the top of the food chain. Early forms of education usually consisted of verbal communications, teaching basic survival. With improved means for surviving, the human race evolved, and grew more complex socially. With this social growth, a greater amount of knowledge was required to succeed within a civilization. The development of more effective ways of passing became even more important for the success of a group of people.

This constant growth in the base of knowledge that is modern society created the need for there to be ever better manners in which to present knowledge to the future generations. The case has been that the growth of society has occurred much more rapidly than change occurs in the methodology by which information is passed from generation to generation. Working towards a more efficient manner in passing knowledge is the founding principle in modern education. With out improvements in the instructional methods of a society, growth will stagnate, and that society will not advance technologically.

The general education of students in America is an important issue. Central to this issue is improving the overall effectiveness of the educational process; in order to increase the interest that the student will have in the material that is being taught. The theory is that with this stimulation, the students will be inspired to continue education and become productive members in American society. Personal freedom has helped our country to get ahead in technology and to remain process. If students are not stimulated and the productivity of future generations diminishes, then this prosperity and well-being could possibly slip away. Technology, the marvelous thing that it is, helps to maintain our prosperity also presents a challenge, because students must now learn how to use these new technologies. Another problem that has been prevalent in American educational systems is that the rate of increase in technology far outstrips the change that will occur in the educational system.

An increased integration of technology into education would ultimately result in students at the least being more comfortable with the new technologies they are exposed to an better able to adapt to them in the future. The ability to learn had become just as important as the actual learning process. The possession of problem solving skills has become a necessity in this modern complex world. Students must learn to be adept at taking on new skills and knowledge to suit there particular needs for whatever situation they will encounter. A well developed thought process and a blanket of general knowledge would assist in the ability to solve problems and adapt. Learning to think critically, analyze and synthesize solutions, or procedures to approach problems related to all aspects of life is critical to the future success of any student.

Current Science Education Theory

"Josh and Chris were very complex"

Current Science education has always been a balancing act between the concrete "hands on" activities and conceptual understanding. During the 60's the pendulum swung from student learning scientific facts and vocabulary to students doing hands on activities. The pendulum seems to be stuck there now. Students still have trouble building their conceptual knowledge from their activities.

Currently the National Science Education Standard emphasizes grades 5-8 the concept developing the skill of "Scientific Inquiry".

> In a full inquiry students begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. [Nat 96]

To develop the skill of "Scientific inquiry" the students need to develop certain abilities. These abilities have been outlined by the National Science Education Standard. First they must be able to identify questions that can be answered through scientific investigations. Second students should be able to design and conduct a scientific investigation. Student need to be able to identify key variables and develop a procedure the will produce the necessary results to answer that question. Third students need to be able to use appropriate tools and techniques to gather, analyze, and interrupt data. Students must be able to apply their mathematical knowledge towards their analysis. Students must also be able to utilize computer hardware and software for their analysis as well. Forth students must be able to develop descriptions, explanations, predictions, and models using evidence. Fifth students need to be able to think critically and logically to make the relationships between evidence and explanations. Sixth student should be able to recognize and analyze alternative explanations and predictions. Students should be open to other ideas and explanations from other students in the class. Seventh it is essential that student develop the ability to communicate scientific procedures and explanations. Finally eighth students need to be able to use mathematics in all aspects of scientific inquiry.

Current research backs up these standards. Science education is no longer learning facts; it is learning the entire universal scientific process. Going from ideas and experimentation to peer analysis.

> Science is regarded as a form of discourse that has evolved as a relatively recent activity of humankind. The goal of science is to make sense of a universe of phenomena in terms of knowledge that is viable. To be accepted as scientific, knowledge must meet several tests. First it must be coherent with other viable knowledge claims. Second, it must be accepted by members of the scientific academy through a process of peer review. Third, it must withstand conceptual and empirical challenges in repeated attempts to refute its viability. Skeptical acceptance of scientific knowledge claims is a part of what is considered acting scientifically. Thus, even at the earliest of stages, an idea is carefully scrutinized in relation to what else is known and efforts are made to refute the claims associated with the knowledge. In the event that the knowledge withstands those tests, the activity of gaining acceptance becomes increasingly social as attempts are made to convince others of the acceptability of what is claimed. When viewed in this way it is apparent that science can viewed as a form of argument during which ideas are formulated and then argued out in a social forum in which efforts are made to persuade peers to a particular point of view. The process necessarily involves the production of evidence and discussion about the extent to which the evidence fits the knowledge claim. As is the case with other forms of discourse conventions and skills are also a part of science. In the past, efforts to characterize these methods have led to oversimplification, with the identification of the science processes, which then were enshrined into approaches to curriculum in a manner implying that such processes had a generic character that transcended the subject matter. [Tob 97]

In a Coparticipation learning environment, students would engage in research and lab activities exploring a particular field. Afterward they would formulate results and conclusions and share with the rest of the class in a forum and through careful scrutinization the class would come to a general consensus of what is acceptable knowledge and what is not. They class would develop its own scientific language. Throughout a course students would constantly swapping between the role of teacher and learner in the community.

A study in 1994 by Driver, Squiers, Rushworth and Wood-Robinson analyzed how students developed scientific understanding. The report stressed, "Experience by itself is not enough. It is the sense that students make of it." [Dri 94] They found that a good blend of concrete and conceptual learning was essential.

"Science concepts, which are constructed and transmitted through the culture and social institutions of science, will not be discovered by individual learners through there own empirical inquiry: learning science involves being initiated into the culture of science." [Dri 94]

Setting Up the Learning Environment

Using small group activities is a great way to establish a learning environment that uses the concept of coparticipation. Many good things can happen in small groups, students my work together on a problem till a mutual agreement is made about its solution. Students may teach others students in small groups as well.

> Collaboration succeeds when students are effective at communicating their ideas and able to help other group members see why their idea contributes to the group goal. It also depends on group adherence to a form of discourse that values argument, reliance on evidence, and explanation. [Lin 93]

Although groups may seem ideal, a lot of things can go wrong. Their peer's social status may interfere with the learning process. If student "A" has a high status often his/her ideas will go unchallenged, even if they are wrong. No discussion will occur because of this. Teachers must help facilitate positive group learning, and orchestrate all the groups in the class toward a consensus that is comparable to today's excepted science.

> Accordingly, teachers need to strike a balance between effective mediation and over*engineering*, by gradually relinquishing control of certain processes and objectives. The assumption is that the students will assume responsibility for the control relinquished by the teacher and employ their greater autonomy to pursue activities to enhance their learning and engagement in relevant and meaningful tasks. If the increased autonomy leads to coparticipation for students then small groups indeed can promote meaningful learning. [Tob 97]

In the whole class setting, things such as demonstrations are a good way to help teach. A demonstration is an experience shared by the entire class. It will open up avenues for whole class discussion. In whole class activities a teachers goals are not to lecture to the class but rather engage students in a discussion about the shared experience.

It has also been noted that in the whole class setting that there should be a 3-5 sec silence between bursts of speech. This pause allows for students to process the information they just heard, making connections to previous knowledge and coming up with questions if they do not understand. This also gives the teacher time to read the body language of the students and decide what direction to go to from there.

Laboratories are a great means of providing concrete evidence to the students. Theories and ideas can be put to the test. Tobin also notes:

> There is a variety of reasons for doing laboratory activities, and these ought to be acknowledged. By making it possible to engage in laboratory activities, students can see what science is like by manipulating equipment and participating in activities not unlike those in which scientists have engaged. Getting involved in standard experiments, such as those associated with pendulums, melting, optics, sound, and studies of plants and animals provide students with insights into the nature of science. What is important here, as in all activities, is that students understand what they are doing and why they are doing it. [Tob 97]

Thought and the Nature of Learning

Cognition described as that which becomes known, the act of learning through experience, perception, reasoning or knowledge. Two important aspects of cognition are perception and conceptualization. Perception involves how the mind deals with the acquisition of new ideas, facts, and concepts. Perception will shape how a student will deal with the information that is presented to them. Every individual will have different perceptions of how things are to occur. Conceptualization describes how a student will then process and store the information that is presented to them. The processing of information generally can be divided into two main methodologies, convergers, and divergers. Convergers, seek out connections to tie together the fragments of knowledge that are gained, while divergers seek to focus on how an idea or piece of factual information triggers another idea. The student will then within their own mind come up with some structure to organize their thoughts. Usually this structure will be either a very linear orderly way, or more random, keeping thoughts as clusters or patterns [Gui 96].

Cognitive science research has presented some important aspects to be improved with the current focus on the thought process in modern educational processes. According to Richard A. Duschl there are three prevalent issues relevant to education taken from cognitive science research.

1. The capacity to learn at any given time is limited.
2. An individual constructs meanings and this ability to construct meanings is influenced by prior knowledge.
3. Individuals Employ and invent rule-directed procedural devices to expand their capacity to learn and construct meanings. [Dus 90]

With these new issues in mind, it becomes evident that learning is an active process of creating links between previous knowledge, and information and ideas that are presented to a student, a linking of "the unfamiliar to the familiar."

The capacity to learn component of this research suggests that the amount of material that can be learned and processed in a given time period is limited. While presented with a large amount of information, there are methods that the mind can use to break up the knowledge, or create meaningful relationships to facilitate learning. This well developed ability to consolidate small bits of information into larger chunks, which will be simpler to recall, is what separates experts from novices. Another skill that is similar to this developed thought process is the ability for experts to "recognize that a certain pattern of information represents a basis for following a particular strategy or drawing a particular conclusion. [Dus 90]" While this skill can be obtained in time methods can be taught in school to help students to develop this process.

The active construction of knowledge supports the idea that students will retain knowledge more effectively if the new knowledge can be meaningfully related to their prior experiences. Therefore, a teacher can more effectively instruct their students by taking the time and effort to provide viable links between new concepts to old information, thereby providing the student with a meaningful whole. The first step towards an effective linking of previous knowledge to new material is to establish what the student's initial understanding of the concepts. This can be done in several ways, the most common being some sort of a pre-test, so that the teacher will have a basis from which to start the new information, and tie it to the old. Secondly an instructor will provide the links for the students to realize, or understand. This can be done in the planning stages of the course, arranging new material in a logical pattern such that there will be some means to tie it all together. Finally effective guidance of the linkage of knowledge for their students requires that a teacher help to provide strategies for the students to make the links, and to see how things fit together as a whole.

One of the biggest misinterpretations to do with education is that of the learner as an individual sitting passively processing the stimuli. This stimulus can come in many forms, primarily as the ideas and information that is fed to students in a traditional educational system. This common misinterpretation of the role of the learner supports the outdated educational system, where students are treated like sponges, forced to take in all the facts, and then to recite them on the evaluations that are given to them. Behaviorist's theory states that the learner is an active seeker of knowledge that sets out to learn by doing, experiencing and engaging in trial and error. In order to fulfill and learn properly a learner must be engaged in the behavior.

One other problem with the current educational system is that it seems that there is a tendency to neglect teaching the students the methods that people use in order to learn. As such the facts and ideas are presented, but the means to manipulate these facts and ideas and use them to serve you is neglected. The wrongful assumption that is often made is that students will "naturally develop procedures that facilitate learning [Dus 90]." The effectiveness of instruction would be increased significantly if the teacher were to guide the student in making meaningful associations between their packets of information. By helping the students to make these associations, the teacher will also foster the development of metaknowledge skills to link prior knowledge with new knowledge.

According to Burton, "learning is frequently defined as a change in behavior due to experience. It is a function of building associations between the occasion on which the behavior occurs (stimulus events) and the behavior itself (response events)." The associations are formed based around the experiences that produce an acquisition of new ideas, principles, or methods. Careful consideration of the needs of the individual learner is essential to proper educational design. The instructor must also take into account the abilities of the learners in order to develop content that is appropriate to the group that is going to be taught. The goals of the instructional process are written in terms of what the learner is supposed to accomplish through practice, and what knowledge that will have gained [Bur 96].

Environmental Factors in Educational Processes

"Chris explained things well,
but sometimes got off topic"

Currently, there has been increasing pressures for students to be adaptable placed upon them by the expanding global economy and societal needs. Public and private institutions are demanding to on critical thinking employees, who can solve a range of problems, yet contend that these types of people are difficult to find. The present educational system is partially to blame for this scarcity of employees whom posses these desired traits. Considerable evidence indicates that today's students are not very proficient in areas of thinking and reasoning and that the biggest problem with traditional instruction is that students will often approach new knowledge as facts to be recited and then to be recalled as a later date. This is not conducive to problem solving where the knowledge that one has will act as a starting point for future development of a student's own ideas.

Five erroneous assumptions have been made and have been governing the educational process since the beginning of the industrial age. These assumptions are as follows: people easily transfer learning from one situation to another if they have learned the fundamental skills and concepts; learners are "receivers" of knowledge in verbal forms from books, experts, and teachers; learning is entirely behavioristic, involving the strengthening of bonds between stimuli and correct responses; learners are blank slates ready to be written on and filled with knowledge; skills and knowledge are best acquired independent of realistic context or use. To suit the much changed global community these early assumptions need to be evaluated and changed to push the educational process towards the creation of students that are better suited to think critically and adapt to a changing environment. With this in mind, there are some new assumptions that should be followed: people transfer learning with difficulty, needing both content and context for learning; learners are active constructor of knowledge; learning is cognitive and in a constant state of growth and evolution; learners bring there own needs and experiences to learning situations; skills and knowledge are best acquired within realistic contexts; assessments must take more realistic and holistic forms [Gra 96].

With these new assumptions in mind, Rich Environments for Active Learning (REAL), which will challenge the student and help them to take an active stance in their pursuit of the acquisition of knowledge, need to be developed. Based mostly on constructionist theories, the learning environment will be shaped with the general feeling that learning is a continuous process where students will build upon, interpret, and modify their own view of reality based on experiences within reality

. Ideally these new environments will also utilize cooperative environments were students will assist each other in the learning process. New environments should include dynamic learning exercises that will force the students to use high-level thinking processes -- i.e., analysis, synthesis, problem solving, experimentation, creativity, and examination of topics from multiple prospectives -- to help students to integrate new knowledge with old knowledge and thereby create rich and complex knowledge structures. This ability to connect knowledge and relate it to what ever a person might be working on is essential to developing a good problem solving ability [Gra 96].

One of the most important characteristics of the Rich Environments for Active Learning is to make sure that education occurs in an authentic learning context. An activity or task will help to present the student with a citation that will be as realistic as possible. In designing these activities, careful attention must be taken to ensure that the activity doesn't exceeded the maturation level of the students or violate other environmental constraints such as safety or cost. Another part of developing REALs is anchored instruction. Anchored Instruction involves the anchored instruction set inside the context of a realistic event problem or theme. In an Anchored instructional system, the student is allowed to explore in system free from and bindings a problem that involves many smaller sub problems through each students point of view. The primary idea within this approach is that it will help the students to experience the intellectual change that an expert would feel when making a discovery or taking on more information about something in their field [Gra 96].

The Rich Environments for Active Learning is also centered mainly on achieving student development, with particular attention paid to intentional learning and lifelong learning processes. Intentional learning is the acquisition of knowledge as a direct result of the student's purposeful, laborious, self-regulated, and active involvement. Important attributes to be developed in the intentional learning process are questioning, self-reflection, and metacognitive skills. Questioning is a key characteristic to developing and intentional learner. The development of questioning skills will serve double duty, while it allows the student to develop more control over there learning process, the ability to create the proper question will also allow the student to acquire information that they seek using well formulated questions. Questioning the material or ideas presented to them will also assist the student in finding more relevance and authenticity to their learning process. Questioning is also a key part to a life long learning process.

Self-reflection is a second skill integral to intentional learning that involves the act of, observing and putting into an interpretation on one's own intentions and motives as objects of thought. By interpreting one's actions, a student can gain some understanding of their place in the world, and how they can manipulate the things around them. The final attribute to be fostered in a rich environment for active learning is metacognitive skills. Metacognitive skills are related to the manners in which people take steps to control their cognitive activity. Cognitive activity is defined as activity related to that which comes to be known, as through perception, reasoning, or intuition; knowledge. If this skill is developed at an earlier age, it will be very useful in the future of the student's career as a life-long learner. The Rich Environment for Active Learning focuses not so much on the synthesis of the facts as earlier educational systems have, but on the proper development of the thinking process. A proper thinking process affords the student the ability to learn more quickly, solve complex problems and to be more adaptable to whatever changes may be put to them [Gra 96].

Cooperative Learning

Cooperative learning is another suggested improvement for the current educational system. Cooperative learning has many advantages over individual learning because it offers some social practice while the students are involved in a learning activity. In a cooperative learning situation, students will share the responsibility for one another's learning while still working on their own learning. Group work is also conducive to argumentation, structured controversy, and reciprocal teaching within the group, and that will help to reinforce the knowledge gained by the students. The support of the group will also allow for students to approach problems that they might not feel comfortable working on with out the group. The group support structure will also help the students to achieve goals that may have been previously been unattainable. When implemented properly cooperative learning is highly successful.

Cooperative learning exercises can be divided into four main types formal cooperative learning, informal cooperative learning, cooperative base groups, and academic controversy. Each type has it's own attributes to bring to the learning environment. In all cases the students will be involved with working together to accomplish shared goals. Group activities work so well because many students perceive that their effort is critical to the success of the group. In cooperative learning the students work together to maximize their own and each other's learning. Interdependence between the students causes the students to feel as if they can reach their learning goals if and only if every member of the group has also reached their learning goals.

In formal cooperative learning exercises, students will generally work together over a length of time ranging from one class period to several weeks to achieve shared learning goals and to complete some joint task or assignment. In a formal cooperative learning situation, the instructor or teacher will have established certain criterion to be followed as well as a plan of how the activity will proceed. The first task for the teacher is to specify the objectives of the activity. Each cooperative exercise it to have some academic objective specifying the concepts and strategies to be learned as well as any skills related to the group skills component of the project. Secondly the teacher will have had to make some decisions related to the logistics of the group, i.e. the size of the groups, the method of assigning students to groups, roles students will have, materials required for the activity, and finally the way in which the room will be used for the activity. Formal cooperative learning exercises are good because they allow the teacher to have a greater control over the outcome of the group activity.

Informal cooperative learning is the second type of group learning exercise. Informal cooperative learning is more along the lines of temporary groups formed to work on a small problem, or get a jump on the homework as a fraction of the total time that the class had spanned. This type of group activity will work to summarize the events of day's class and help to reinforce knowledge that is gained. Putting the students into these groups in addition to the lecturing will force the students to cognitively process what they have learned in a class and apply it problems, instead of just taking down notes. This will have the positive effect of forcing the students to use the new knowledge when it is fresh in their mind.

The third type of cooperative learning is the base group. In cooperative learning base groups, there are long-term heterogeneous cooperative learning groups. Base groups provide students with long-term peer relationships that will support the growth of the students. The base groups meet to discuss academic progress of each of the members, to provide assistance for one another and to verify that each participant is completing their academic program in an acceptable manner. They may also help members who may have been absent to catch up, and learn the material that they have missed. Informally the members of these groups will interact through out the day discussing homework, and other issues that would be facing students. Base groups also help to improve attendance, help to personalize the working aspects of school, and overall improvement of the quality of the work.

The final type of cooperative learning situation is academic controversy in which students of incompatible ideas work together to reach an agreement. This type of cooperative learning exercise is set up in a manner such that one group of students will take the "pro" position, and the other group will take the "con" position on the topic that is to be discussed. Students are then held to follow the five step controversy procedure of (a) preparing the best case possible for their assigned position, (b) presenting their best stance to the other group, (c) having and open debate over the issues, (d) reversing perspectives, and (e) dropping all advocacy and working together to find the whole groups best judgment on the subject. This type of cooperative learning builds strong interpersonal skills because it forces the students to present their ideas forcefully to their peers, a situation that will be repeated countless times in one's life.

The theoretical foundations of cooperative learning are based in behavioral theories, cognitive development and social interdependence theories. Social interdependence exists when students work together to achieve a common goal, where the success of the group is affected by the actions of others. Interdependence can be either cooperative or competitive. In a situation where social interdependence is occurring, the group dynamic will be more that of a whole then that of the individual. The quality of the interdependence will have a great effect on what the individuals will take out of the situation; generally, positive interdependence will inspire students to work together where as negative interdependence will cause the groups to become more splintered.

Positive interdependence is the type of interaction that is the target of group activities. In positive interdependence the group members will promote each other's success, as well as the success of the group. Students involved with cooperative learning activities where the members that are interacting positively will give and receive help in both work related and personal issues. Members in the group will exchange ideas and resources a means to promote the success of the group as well as the individuals. This exchange of ideas has many different forms all of which are important to the acquisition of knowledge by all involved in the activity. If there is a bulk of material to be gone over, a group could split up the work, each covering some amount, the summarize what they covered so that the other members can learn from it. Another positive exchange is when a member of the group will teach their knowledge to other members on the group.

Positive group interdependence also gives feed back to the students in the form the discussions that will be present in the activity. Immediate feedback can be helpful in reinforcing the cognitive aspects of learning. The combination of ideas in the group will often lead to some conflict between different members of the group. This conflict will cause the group members to challenge each other's reasoning, and promote a healthy debate that will serve to force the students to make decisions, and to gain greater insight into the problem that is posed to them. Positive group interdependence also helps to foster increased efforts to achieve; encouragement of others will tend to increase one's own desire to achieve. The inputs of all of the members of the group will cause there to be some mutual reasoning, in which members of the group will influence other members while seeking themselves to be influenced; this is evident when a group will quickly adopt more efficient ways to complete what they are doing. The most important effect of positive group interdependence is that students will learn ever so valuable interpersonal and small-group skills through their self-evaluation of working together and how the group's effectiveness can be continuously improved. [Joh 96].

Technology & the Classroom

Throughout the 90's and now in 2000 there is still a raging debate about the effectiveness of computers in the classroom. It is still to early to tell what fate computers and education will have. There are two educational issues at hand here learning how use a computer and using a computer to learn.

One major problem with computers that is unavoidable is there cost. School systems find themselves devoting huge portions of there budgets to wiring there schools and classrooms with the latest computer hardware and software only to find that the hardware has become obsolete & the teaching staff has no clue how to use it. But let us not jump to conclusions too soon. Having the latest and the greatest technology in the classroom is not some cure all remedy that ensures that kids will be able to learn with it. Two key factors in the success of computer-aided learning is 1:the teacher's ability to use a computer 2: his or her ability to integrate its use into the classroom. A school system's first responsibility is to make the faculty computer competent. Teachers need to be taught how to teach with computers. The Internet is a wealth of information you can access current events from various Newspapers & News Television stations online & data from thousands of public and private scientific groups. Teachers just need to learn how to incorporate this into the classrooms.

Procedure

"It was so much fun all the kids in the other classes are jealous they don't have you."

Once all of the required background information on educational theories was gathered, it became necessary to start the development process of your project. In this section we will develop the lessons that we are going to give, with the demonstrations, labs and other parts of the class that we will be doing. We intend to do this in an iterative manner where we will develop a lesson and then teach it, evaluate our results in a number of manners, and make improvements based on the results of our earlier work. In this manner we will build off of our research, put the research into practice, and then build upon the results of our work, to attempt to optimize the effectiveness of our teaching strategies.

Initial development

In the initial development of our addendum we set out to gather some background information about the students. The first thing done to start this part of the project was to survey the students to determine the amount of interest that the students had in science class. The survey covered mainly what areas of science would they be interested in learning more about, and how they would like to see science class changed. Included in appendix A is the survey followed by a tabulation of some of the more exemplary results that the students gave.

The first question that was given to the students was "Is there anything that you would like to learn more about related to the area of science?" the students were then given the option of motion, electricity, sound waves, heat, energy, magnetism, light waves, and other. Initially, we had left this question the be open ended, but our Project advisor at Choockset Mary-Beth added the selections which was probably a good idea, because it allows students to select things rather then have to come up with their own ideas. This question was aimed at selecting some of the material that we would cover in our lesson; the project was calling for something in the area of physics or chemistry. This question was pretty straight forward, so there was not an extreme degree of variance between the different. This survey yielded that electricity was the topic that the majority of students were interested in learning about (67.5%). The topic that was of second most interest was magnetism, which was selected by 59.7% of students; following closely were sound waves, heat, energy and light waves, of which all shared about a 29.9% percentage of students who were interested. Motion was at the bottom of the list with 19.5% of students that were interested, and there were a few write-ins, most notably of which are chemistry and biology.

The rest of the questions were aimed at gathering insight into what the students felt that would help to make the class more interesting, as well use the input to help guide out development of a course that is to be interesting. The first question in this group was: "If given the chance, what would you do to make science class more interesting?" Typical responses to this question included comments about increasing the amount of demonstrations, and hands on activities. Many also suggested that the number of group activities, and projects as they felt that these activities would augment the interest level of the class during a period. Many also suggested playing more games during the class period. The next question was: "has there been a particular class or demonstration tat you found particularly interesting?" Most common answers involved the similar trends to the above question, with the students particularly likening different labs, or demonstrations. Not being trained as elementary educators, we put this question in the survey to help gain some insight into what may or may not work to keep the students attention.

The next two questions on the survey were aimed at getting some background information on the students on how they feel about science class, and kind of how they felt about their own ability to pay attention in class. A majority of the students said that they enjoyed science class. Most of the students who liked science class said that it was interesting, and that they like learning about things. Typical complaints were usually about the repetitiveness, or complaints about the particular types of work that had to be done. Comments about an inability to pay attention were usually supported with reasons such as the class being boring, or if the students were just taking notes.

The final three questions were about the actual structuring of the class. Question number six stated; "do you like working in groups or individually?" Ninety-four percent of students said that they preferred to work in groups. Those who did not would cite reasons like they had trouble concentrating, or found it difficult to meet with the other people in their groups.

Question seven was directed at gaining some information about some ideas that we had for developing our addition. We thought that it might be fun to put in some little competition for the purposes of getting the students excited in what they were learning about, and giving them the ability to challenge themselves in and academic oriented competition. The question posed was; "do you think that a group science competition would make class more fun and interesting?" Seventy-two of the seventy-seven students stated that they believed that it would make the class more interesting. This was pretty good news to us because we were considering that some sort of competition would help to serve our goals of making the class more interesting for the students.

The final question was; "do you enjoy lab activities? If no what could be done to make them better?" Once again, ninety four percent of the students surveyed said that they enjoyed lab activities, for reasons such as, they are more interesting, or the students like the ability to do hands on work. We took all of this information into account when starting the development of lesson plans.

When we initially sat down to develop the plans we realized that it was a slightly more difficult task then originally anticipated, which required some further research on our part. To initially begin the lesson development, some research into simple educational practices was necessary, being that neither of us are educators; we did not fully realize the complexities of educating students. Once we had gathered all of our material for the educational theories, and practices, it became necessary to gather some background information, more specific to the implementation of the lessons that we were developing. Chris worked on developing the content where as I worked on gathering the information on specifics of implementing lesson plans and the ability to measure our effectiveness, so that we would have some material to put into the results section of our paper.

We also came in during a laboratory session to observe the students working in as they would in a normal lab. This was useful in giving us some idea of what the students were capable of handling, and what we could give them. We were also able to observe the different types of students that were in the class. Based on earlier discussions with

Mrs. Petit, we figured that for all group activities she would be responsible for choosing the groups since we do not know the students as well. At this point we also looked through some of the lab materials to determine what would be well suited for the labs and demonstrations that we were planning.

Development of lesson plans

The proper development of lesson plans is a fairly difficult task; a lesson plan consists of several main parts including goals, objectives, prerequisites, materials, lesson description, lesson procedure, and finally assessment or evaluation. Goals would cover the specifics of what the instructor intends for the cover in the lesson, as well as set the stage for the manner in which learning will occur. Objectives for the lesson can be divided into four main subsections, behavioral objectives, learning objectives, instructional objectives, and performance objectives. Behavior objectives are those that are related to material surrounding the curriculum, i.e. they deal with what material is to be covered by the instructor. Behavioral objectives specify some kind of behavior that is observable through the actions of the students. Behavioral objectives are a description of the intended learning outcome, and as such can become the basis for the rest of the lesson development. The behavioral objective also helps to shape the manner in which the instructional development will occur, and how assessments of effectiveness can be made.

The in order to collect the information needed to successfully document our work, we will require some ability to meter and compare the results of our efforts. The proper development of Behavioral objectives, will afford us that ability to make inferences, or measure the effectiveness of the material that we are teaching to the students. Behavior objectives are constructed in three parts: the conditions, the behavioral verb, and criteria.

Conditions cover the situation in which the desired behavior is to occur. Conditions specify the material, directions, circumstances and commands that the student will be given to initiate the behavior. The behavioral verbs are a specific list of actions that are observable through the actions of the students engaged in the learning activity see appendix B, for this list of verbs. The verbs are intended to denote an observable action, or the creation of an observable product. The criteria are a set of descriptions of to what extent the intended behavior must be performed to meet the behavioral objective. The criteria are usually expressed in a minimal number of tasks to be completed in order for the learning activity to be done. One important part of the behavioral objectives is that they are related mainly to the curriculum, and not to the teaching, or the final grading of the students.

In order to document the results of our project, we will use the behavioral objectives to help evaluate the effectiveness of our lessons; we will figure that if the students are able to learn, then the lessons that we are teaching are effective. Proper development of behavioral objectives will also help us in the process of evolving our lesson planning in order to make our instruction, more effective, and stimulating.

Once the objectives for each lessons was set, we began the work on further flushing out the lesson plans. This included filling in our instructional objectives, the objectives that we will set for ourselves to accomplish as teachers. Materials required is another section of the lesson plan that will require some development. Materials include all handouts, worksheets, demonstrations, and lab materials that will be used during the lesson. The materials section also helps the instructor to organize the material and determine the preparation time that will be required to get the materials together to efficiently present the materials.

With the lesson objectives defined and the materials set aside it is time to write the lesson procedure, this is an outline of how the lesson is to scripted out to the students. Developing the procedure must keep in mind the students capacity to learn and not present to much information in one period. This task, of determining the eight-grade students capacity to learn is a little beyond us at this point. We spoke with Mrs. Petit, and she said that roughly 3 spaced out notebook pages is the typical amount of information that will be covered in one day. For the first lesson we intend to bring more material that we think will be necessary just so that we will definitely have enough material to cover.

The final section is the assessment; this is tied closely to the criteria section of our behavioral objectives section of the lesson plans. In a lesson plan that is being used by an instructor, this part would usually be the section that the student is getting evaluated on, but since the work that the students do for us is not really for credit, this will be more of an evaluation on the success of our lesson plans.

Now that the basics of writing lesson plans is completed, we began the difficult task of assembling the information that we had into a structured lesson that will ultimately be taught to the students.

Lesson Development and Implementation

"Josh was a little better"

In the following sections, we will discuss the development of each day's lessons, how the lessons went, and finally how we learned from each lesson, and how that new knowledge can be applied to future lesson plans and materials. We were limited by conflicting vacation times between us and the eight grade students to going in and teaching ten lessons, two a week for five weeks. Since neither of our experienced as teachers

Lesson 1 Preparation

The first lesson that we will be covering is Basic Atomic Theory. There are multiple reasons for choosing this as our starting point; the main reason is that it is the starting point of the extensive electrical unit that we will be covering. Other reasons are that it is fairly simple and seems to be a good choice for getting our feet wet in the teacher's shoes. It will also be a good test of the amount of material that we can cover in a day, and the amount of depth that we can include in our instruction.

As defined in the objective part of our first lesson plan included in appendix C we had intended to cover the following material:

> **Objective**: To define what an atom is to the students, and to illustrate the different pieces of the atom. To show the students how matter is composed of atoms, and the difference between elements and compounds. To demonstrate the Bohr atomic model, and show how atomic structure affects materials insulating properties. For us to gain some experience with teaching and to become more comfortable teaching the students.

Lesson 1 Review

For the first day, we used a very formal form of the lesson plan. This plan included a Purpose, objectives, behavioral objectives, criteria, and procedure. This followed the basic format as prescribed by a variety of online teaching resources. With this well planned out lesson and the material that we had gather intended to go in and have a very successful time in class. With this in mind we went into class, with no previous experiencing thinking that everything would go perfectly with every student understanding all of the ideas that we were to be presenting to them. So we went in on Wednesday March 14, 2001 to teach our first day of classes. This was an important lesson for the development of our own teaching styles since we were slightly apprehensive about how things are going to go. With no experience in the field, this lesson will become the reference from which each of us will compare, and improve the future lessons upon. We also created a Letter to distribute to the parents of the students so that the parents would have an idea of what we are doing. This letter is included in appendix D.

Overall the lesson plan for the day went as well as could be expected, neither of us have had too much experience with being on the other side of teaching. In the beginning of the lesson there was some nervousness that was associated with standing in front of a class doing something that we were completely unaccustomed too, but as the class period persisted, we became more relaxed standing up in front of the class. This nervousness caused there to be a slight rushing of the material, and an occasional stutter when explaining things.

As far as the material is concerned, initially we had thought that we might not have enough material to cover, but as it turned out we were unable to cover all of the material that we had initially planned, and we ran sort of fast. For the first day we gave a pre-survey which we have included in appendix E to the students to start off the class so that we could get some sort of a before and after picture of the material that we are teaching. The presentation of the bulk of the material that we were to cover went fairly well, in some feedback that we solicited from the teacher Mrs. Petit regarding the lesson; she said that everything went fairly well, but that we could make improvements by slowing down a little, and stressing the important facts. From her experiences she said that it was effective to outline more specifically the important facts that the students should take down into their notebooks since it is likely that at the eight-grade level, they have not perfected the note taking skills that are vital to being a successful student.
The most important lessons that we gained in this first experience were some improvements that could be made to our utilization of the lessons plans. Most notable of these improvements being more specific in creating a better planned out class period including, the visuals, and other required instructional tools. The instructional tools that are most important to describe include having all of the material that was to be put on the board including definitions and figures. An improvement in the scripting of how we would present the material to the class would also help to improve the effectiveness of our joint teaching effort. The material that we had was good, but it seems that a better presentation would benefit all.

Lesson 2 Preparation

Upon reviewing the pre-tests that we had administered the day prior of today we decided that it would be beneficial to the students if we reviewed the atom a little more since it seemed that they were slightly confused. With this in mind, rather then moving forward into electrostatics, we elected to review with the students and try to make sure that all of the class is following, rather then loose them from this early stage of our lessons. Once the review was completed, we started teaching the material about electrostatics. The new electrostatics material that we planned on covering included the properties of electrical charge, and how that charge behaves when being transferred or built up.

With some of the lessons learned with our first day of teaching experience, we chose a more pro-active approach to developing a lesson plan, instead of a numbered out-line of what we were to cover in the day, we developed a bulleted list of what we would be doing exactly. Included in appendix F is the lesson plan for lesson 2. This included specific diagrams, cues, to do specific things, and questions that we wanted to be sure to cover. This gave us a strong backbone from which we were able to expand. We found this to be very helpful since it helped to prevent us from loosing focus and getting to a point where both of us were looking for where we had to go next. This is one point where we feel we will definitely have the ability to refine the lesson plan till it is most effective for us. We dubbed this new style of lesson plans out plan of attack or P.O.A. for short. In the future lessons, we will adhere to this method making improvements to it to facilitate our task of teaching the students.

Lesson 2 Review

For this lesson, we had planned to do a little recap of the atom, and then to move into the basics of electrostatics, we had planned a series of demonstrations including, some which utilize the plastic rods, rabbits fur, silk, and electroscope, glass rods, and the standard static electricity paraphernalia. I will admit that we were kind of excited about this lesson since we felt that the students would really enjoy the Van De Graaff demos. Being all excited about it, and still having some difficulty picturing the amount of material that we would be able to cover in a day, we came up with about twice as much material then we needed. This was not to worry though, because we have no set requirements to cover so we are able to roll stuff over to the next day's lesson. With the feeling that the students were going to enjoy the material that we were covering made it easy to come up with stuff to present to the students.

Mrs. Petit suggested that we give out some handouts, provide the students with something to hold so that they will have something to look at while we move along at this rapid pace. In this lesson, we had planned to cover the different modes of transferring electrostatic charge, but since we did not we have moved that along with the demos of each to the next days lesson, with which we will incorporate her suggestion, and provide the students with a worksheet to be completed with us, centered around the transfer of charge along with a review sheet for a post-test that we will be administering.

Lesson 3 Preparation

In the second lesson we ended up mostly covering the atomic structure material, it is becoming evident that the infrequency of going in to teach lessons has turned out be a limiting factor in our ability to teach the students. So in lesson two we did not really move too deeply into the electrostatics as we had planned. This made the task of preparing for lesson three much easier for us. We worked on further improvements to our lesson plans so that we could move more efficiently. For this lesson we specified what each of us would be doing during the lesson presentation. This scripting of activities would serve to better organize us to teach the class. We also worked on a worksheet about transfer of charge that we planned to go over with the students. We have prepared the posttest for the atomic and electrostatics units, so we decided to give the students most of the material that we would be covering on the exam to see how much of it they retained. We could help use this to compare against the pre-test to see how much of the material the students retained. Included in appendix G is the plan of attack for lesson 3.

The ability to compare how much the students knew about the subject matter before and after we taught is important because we will need some stuff for discussion in the latter parts of this paper. To prepare for this lesson we also ran though the demos that we would be doing to make sure that it will al work well. This was good because we realized that we were going to have some difficulty based on the fact that it was very easy to build up excess charge on oneself, which would interfere with the very sensitive electroscope that we were using. We also encountered that it was much easier to build up a negative charge via the rabbit's fur and plastic rod then we could with the glass rod and silk. We also "found" two milk crates to use as insulating platforms for use with the Van De Graaff for experimenting with the generator. This allowed us to charge some of the larger spheres that we borrowed from the physics department with out shocking ourselves.

Lesson 3 Review

Overall lesson three went very well, the students really enjoyed the demos that we did, and they seemed to be better able to stay focused on the materials given the abundance of visual learning aids that we gave to them. These aids came in the form of a lot of demonstrations using rabbit's fur, plastic rods, silk, glass rods, and the electroscope. We also did a few demonstrations using the Van De Graaff generator, including, making sparks, attempting to make peoples hair stand up, and doing a shock ring where the students all held hands in a circle. The students enjoyed seeing other people getting shocked, including their vice principle. Once again, we did not get to cover all of the material that was planned, so we will cover the worksheet that we had provided for the students to do in class tomorrow. To keep interest levels a little higher we decided that we would have the students volunteer to help us out with the Van De Graaff demonstrations that will be covered on the worksheet.

The success of this lesson probably came for a number of reasons, since this material was being pushed off; it gave us a lot of time to prepare the materials. We also had the lesson plan scripted out very well as far as how we would interact in presenting the material, who would be writing on the board, and who would be talking, and finally who and what would be demonstrated.

Says Chris of lesson 3, "Today went very well. We had too much to cover and actually ran out of time. The students we much more involved, asking questions when they did not understand stuff. I walked away feeling as thought the students really got something out of that lecture. We got to have fun with the students at the end of the class playing with the Van de Graff generator, making peoples hair stand on end. And we concluded the class by doing a shock ring. The teacher e-mailed us back saying the student where all talking about the demo on the way out of class. I think we made a real good impression today."

Lesson 4 Preparation

For this class period we were continuing with the different methods charge transfer in static electricity. We decided to have the students run the demos using the Van De Graaff set to a low out put of the demos. The class could then follow along and fill out a worksheet that we provided to them with little pictures of spheres on which they would show charge distributions and transfers. Because this material was not too different from the material that we had covered the day before we elected to not do to much more preparation for the day and just let things happen with out as well of a scripted lesson plan as we previously had. If nothing else, this would help to test our abilities as teachers. Appendix H shows the material that we put together as well as the charging methods worksheet that we went over with the students.

Lesson 4 Review

Well first off it was raining today and thus not an ideal day to be dealing with static electricity. We had the students run two demos one about conduction charging and another that dealt with inducing a positive charge onto a sphere with a negatively charged sphere. The first sphere did not really work, we figure that the charge dissipated through the moist air, and the second demo seemed to work okay. The students did not seem as interested today, and we ran short of material.

On the Wednesday before we went in to cover this lesson we had started in on the electrostatics that we were to be teaching the students. The first part of this lesson went really well, however, we had planned to fill out a worksheet with the students. Time did not allow us to get to this point so we had to push it off to Thursday. On every lesson, we had planned too much material and did not get around to presenting it all so we decided accordingly that we were just going to cover the material that the sheet had, and do a little review for the Post survey that we would be giving the students. With this in mind, we did not make a well-structured lesson plan like we had one some of the earlier lessons. This left us shooting from the hip when we went into class, and while we managed to fill the time allotted, both of us felt that we did not like not having out lessons set out in front of us, and resolved to always be prepared for the classes that we would be presenting to the students.

Another event to come out of this was in the end of the class, Chris went on to explain the difference between DSL and cable, but blew the students away with specific numbers. If nothing else, this help to demonstrate what capacity the students have learn. This made much more evident, how the students will shut off their minds when specific numbers are presented. They seem to be much more able to learn if concepts, generalizations or diagrams are used. Putting things into terms of units, that the students are not familiar with seems only to loose the students.

Lesson 5 Preparation

For lesson five, we planned on administering a test to the students to help evaluate how the kids learned and the effectiveness of our instruction. We were not sure how long it would take the students to complete the exam, but figured that it would take most of the period so we did not prepare any new material. Knowing basic electricity pretty well, we figured that if need be we could just move on to the next topic that we would be covering if need be. The exam that we gave to the students is in appendix I.

Lesson 5 Review

We started out the lesson by having the students ask us questions to makes sure that they understood everything. Most questions were centered on the students trying to figure out what kinds of questions they were to expect to see on the exam. This type of behavior is not surprising, because we were new to the students and they had not yet seen a test from us. They asked specifically if we were looking for definitions, or exact numbers. Our feeling was one of if they demonstrated that they learned at least the concepts then their answers would probably be good enough to receive credit for them.

The students took the test in probably about half an hour. With the time remaining, we took a vote to see what the kids would like to do, they were given the options of reviewing the exam, moving on with our material, or letting their normal teacher Mrs. Petit move on with what she was teaching. The vast majority of students voted on reviewing the test. The questions for this part were mainly the students trying to figure out how well they did. They also asked if we would be giving credit for certain answers.

Review of First Test

Exam I covered basic Atomic theory and electrostatics. You can find a copy of the exam in appendix I and the results in appendix J. The exam was 10 questions long. The first 7 questions covered atomic theory and were very short answer. Problems

8-10 demanded a little more they were given various situations involving charged spheres and were asked what charges form were. The student took the exam in pairs. There were 10 pairs of students. The results were very encouraging. The average was 88.5%. Everyone scored above a 75% except one group.

Here are some of the most common errors we found on Exam I. First, there was not a consistency with the labeling of the electron shells. Here are some of the varied results. This can be best explained, by our definition. Throughout the beginning lessons we referred to the electron shells, also as the electron orbitals. We also talked about the outer shell being the valence shell. We were lenient with the grading of this particular label, after we realized the whole confusion of this was mostly our fault.

Atomic shells
Valence shells
V shell
Outer layer
Outer orbital shells
Electron rings
Problem 2 Common Errors

Only half of the groups got number four correct. Problem four asked "What makes elements different from each other?" They either answered correctly with the number of protons or pretty gave us an answer that included protons, electrons and neutrons. Answering with all three sub-atomic particles is a very logical answer that is wrong and is why we asked this question in the first place. We stressed this point a lot, but still the students went with the logical choice

Only 4 pairs answered problem 5 correctly. The incorrect responses varied from strong or weak nuclear force to static affinity. This can be accounted for by just lack of studying.

Just about everyone answered problem 6 correctly, with the exception that only half could answer with the correct term. Everyone knew that you would have a positively or negatively charge atom, they just did not know it was called an ion.

The only other noticeable problem was with problem 9. Many students forgot that when the spheres come in contact and disperse between the 2 sphere there is still a net negative charge on both.

Lesson 6 Preparation

After the test we started our move into electricity and circuits. The primary area of interest for this lesson was getting the students to understand the concepts of voltage and current in order to move further into electricity. An attempt was made to tie what they had learned in static electricity to what they would be learning about in the future. To try to simplify the concepts of electricity for them a little bit, the fluid analogy was used. The fluid analogy calls for drawing a closed loop of piping with a pump and a valve, where the pump is treated as a voltage source and the valve is treated as a resistor. While this is a good model for demonstrating current, it does have some limitations in demonstrating resistance, particularly if you attempt to add resistance and also the manner in which a pump works is different then that of a battery.

Lesson 6 Review

Lesson six dealt primarily with electricity, included in appendix K is the plan for lesson 6. Since it was an introduction we used the pump/fluid analogy to describe how current and voltage work. This worked very well for getting the concept of current, the flow of electrons across to the students, but the voltage is what they had the difficulty understanding. We attempted to break it down for them, but were unable to successfully achieve an overall understanding. The students seemed to have great difficulty understanding the concept of voltage. Attempting to tie the concept of voltage with the static electricity that we had discussed with the students, we tried to relate voltage to the kinetic energy of scuffing your feet along the ground, which is converted to potential energy in the form of the stored electric potential energy. The main purpose was for the kids to gain an understanding that current is the flow of electrons where as voltage is just the potential electrical energy difference per unit charge. To try to help out this understanding, we moved onto how a battery works.

Next we discussed how a battery worked, which once again the students had difficulty understanding. The effort would have been better spent showing the students that the battery merely serves to convert the stored chemical energy to electrical energy providing a constant source of voltage, or potential difference. Once again spouting off the specific names of chemicals and reactants and the resultant products seems to loose the students. Time came to a close rather quickly on this day so we had to end the lesson early with the students still pretty lost about what the concept of voltage is.

Lesson 7 Preparation

To start out this lesson 7, a continuation of electricity, we would start out by doing a recap of voltage and current. This basic understanding of electricity is essential for success in future exploration of electricity. The lesson plan that we had used the day previous still needed to be covered so only the addition of a bit more new material was required. The added material would deal mainly with electrical circuits, the schematic representation of them, and the addition of resistance in series and parallel. The plan of attack for lesson 7 is included in appendix L. To start on this more application based bit of knowledge, we started by giving the students a sort of key to schematic representations. We took an object that most students would be familiar with and drew a cutaway of it. Next to the cutaway a schematic representation was made. The students were then asked what parts of the schematic were in relation to the physical model. The primary purpose in doing this was to establish a key to the components of the circuit diagrams, and to get the students comfortable in dealing with them so that they would be able to construct their own circuits.

Lesson 7 Review

Today we went in and continued on our lessons in electricity. We started with a recap of the lesson before, continued with voltage and current then moved into electrical circuits, circuit elements, and combining resistances into equivalent resistances.
We drew a flashlight on the board and then drew the equivalent circuit diagram so that the students could relate the different physical components with the circuit diagrams. We elicited some input from the students about what we would consider conductors, or electrical elements. They had a tendency to name all types of materials that acted as

conductors where as we were looking for more generally wires, foil, and things of that nature.

The students seemed to take on the circuit section of the lesson better. From the looks on their faces it seemed that they definitely felt some understanding of this part; it is uncertain if this is because the concepts were simpler, easier to see with the diagrams, or if it is because they can identify and relate this with things in there every day life. When we told them what a resistor is, one student said, "ohh that is what those things are," implying that they had seen them and pondered upon their purpose. This feeling of getting the students to relate the knowledge that we are presenting them with bits of thoughts that they already had that seemed to be the most rewarding.

Lesson 8 Preparation

For the eight-day that we were going in to teach the students we decided to do a lab. This lab is included in appendix M. The lab would follow 3 main stages. In the first stage the students were going to use a light bulb to help visualize how much current was flowing through a circuit. In the first part of the first stage the students created a circuit that had a light bulb hooked up to two batteries, they were told to make a reference to the brightness. Next they added a 25-ohm resistor in series with the circuit, once again they were supposed to record the brightness of the light bulb. The final part of this first stage was to add a second 25-ohm resistor in parallel with the first. The Purpose of this first stage of the lab was to show the students that there is more current through the light bulb when the two 25-ohm resistors were in parallel.

The next stage of the lab had the students apply the equivalent resistance formulas to come up with some equivalent resistances by using four 50-ohm resistors, we had them fill out a sheet where they would draw the equivalent network of resistors to achieve the desired resistances. We were then to circulate through out the room to check these numbers so that the students could start on the next part where they would be inserting the circuits that they had created into a test circuit that would use an ammeter to measure current.

Lesson 8 Review

Today we had the students do a lab trying to determine a few equivalent resistances and then measuring the current through the circuit in order to try to determine Ohms law. To begin the lab we had the students hook up a circuit with a just a light bulb in it and note the brightness. They then added a 25-ohm resistor in series with the light bulb and record the difference between the intensity. Then we had them add a second 25-ohm resistor in parallel with the first and recorded the different brightness. The principle was to get them thinking that the parallel arrangement reduced the resistance, so that in later parts they would be able to come up with equivalent resistances.

When they were coming up with equivalent resistances they would get the 25-ohm R_{eq}, but when faced with the 12.5-ohm R_{eq}, they often put three 50-ohm resistors in parallel implying that the third would halve the 25-ohm resistance. For this part since the series parts were easy they seemed to pretty much guess for the parallel parts that we were looking for. It became evident early on that we had not laid out the guidelines for doing the lab explicitly enough as many of the kids embarked upon their own experimentation. The ammeters that we borrowed from the WPI physics department were kind of old, and maybe a little to fragile for use by the eight grade students because by the end, half of the meters that we had brought were bent, or broken. The students also did not record their results or calculations on their own sheets.

Over all from our standpoint, the labs were a nice change from standing in front of the class and lecturing, we got to interact more with the students, and they got to experiment and discover some things for themselves. We had thought that the students would naturally write out calculations on the lab worksheet, but once again being so far removed from the eight-grade, our predictions were wrong. If time permitted for there to be a second lab, the instructions would be much more explicit, and we would work slightly more diligently to keep the students on task. Part of the problem seems to be that the students were aware that the work that they were doing with us would not negatively affect their grades and as such did not work to hard at the lab

Lesson 9 Preparation

Since lesson nine was a continuation of the lab, it did not require that much preparation. We met however and discussed some points that we wanted to make to the students to make the lab move more smoothly. First of all we told the students that it was required that each of them fill out the lab hand out. We also asked the students to write out the calculations where they were asked to find equivalent resistances since the day prior many were just writing the answers. For lab session most of the students will be working with the ammeters and recording the data to try to derive Ohm's Law.

Due to the time constraints that were placed upon us by vacations that did not line up, we were forced to cut our lessons short. In fact we went in an extra day to try to finish up the lab so that we can do another lesson before we gave the students the final test on electricity. In order to teach the students the work, we developed a worksheet that came with several example problems done out step by step to help the students work through the problems.

Lesson 9 Review

In general the lab went fairly well. The students made observations about the light bulbs in the first part and recorded those. Many commented on being able to grasp that when the resistors were in parallel, there were more paths for the current to flow, and thus less resistance. This was an essential step in getting them to come up with the equivalent resistances particularly the 25-ohm and 12.5-ohm resistances using 50-ohm resistors. Even though the students were given the formulas for determining equivalent resistances, it was not completely obvious that given a set value of resistor, you could achieve a lower value by putting them into a parallel arrangement. We may have misguided them slightly in this aspect since many put two 50-ohm resistors in parallel in order to achieve the 25-ohm. When they asked if this was correct, at first we would say yes, where as a better answer would have been, "well why is that the case?" to see if they would at least consult the equation for equivalent resistances. When asked to come up with the 12.5-ohm resistance many simply added another resistor perhaps to halve the value again. This time when explaining what they had done wrong, we would work through the equation with them to see that it is actually a function, rather then a guess.

When it came to actually putting the circuits together and taking measurements there were a wide variety of problems. The most common problem that we saw was probably having the ammeter hooked up backwards. Another problem that was encountered fairly regularly was the ammeter being used in the wrong range. There were also some problems with the batteries being hooked up wrong. Through observations, it was determined that most groups were able to get at least some correct data. It seems like some students may have used the 25-ohm resistors in this part, which may have thrown off the measurements. Many of the ammeters were also kind of messed up, before the lab we checked each one with a few different resistors, but after being exposed to the onslaught brought upon them by the eight grade students many of them fell to pieces. We had the students approximate as best as possible. Good data was actually required to find how the values relate.

When it came to actually deriving Ohm's Law there were a few factors that seem to have impeded the students ability to find the relation. First of all it would have been beneficial to denote explicitly that Ohm's Law deals with voltage (volts), current (amps), and resistance (ohms). Since the meters read in milliamperes many of the students were trying to use the values of current in milliamperes, and while the relation is still there, it would be less evident and thus harder for the students to come up with. Some students came up with the relation with out any assistance, while others did with a little guidance. The first bit of guidance that was usually offered was to pick a group of numbers that they had that were fairly close to the hypothetical values that they should have been achieving. If they were still confused we would say something to the extent of, "try applying simple mathematics such as adding or subtracting them." This almost always got them to achieve the proper answer.

Lesson 10

Lesson ten occurred the day before we were supposed to leave. To help the students as much as possible we did a review of electricity. Mostly we went over the homework that we had assigned. We made a point to work over problems very similar to those that would be on the exam. We were also sure to make sure that they knew that the equations for Ohm's Law and finding equivalent resistances would be very important to know. Another difficulty that many of the students were seeming to have was the procedure for breaking down a complex circuit into it's smaller constituent parts to simplify it to one equivalent resistance.

Lesson 11

This was the last day that we were going to go in and work with the students, as promised we brought them munchkins and juice. To bring our efforts to an end, we planned to give the students one final test. The test would cover some of the material that we gave to the students on basic atomic theory. By doing this, we were checking to see how well the students retained the material that we had thought. The test, included in appendix N, was made up of two parts; the first part was multiple choices, while the second section was a short answer where the students had to do some calculations on electric circuits.

Just as we had done with the last test that we had administered to the students we started out the class by having a question and answer session. We also took the time to stress the importance of remembering Ohm's Law and the equivalent resistance formulas. To assist them we also drew a complex circuit diagram, which we broke down with them in order to show the students the proper procedure for breaking down complex circuits. An example of doing an equivalent resistance calculation for both series and parallel arrangements of resistors was also done. We consulted with Mrs. Petit

Review of Final Test

Exam II can be found in appendix N and the Exam II Results can be found in appendix O. Problems 1 through thirteen were multiple choice in order for us to solicit more information from the students in a shorter amount of time. Twenty-one students took the exam out of which one or two students missed a day or two out of the lessons. Additionally about seven of the students had to leave fifteen minutes early for a band field trip.

Problems 1-4 where general review we expected students to retain most of this considering they did so well in Exam I. Problems 6-10 where general electricity question that we expected them to know. Problems 11-13 were very analytical and required the student to have a very deep understanding of the electricity material that we had covered, we expected this section to be about 50/50, but it turned out to be worse. Problems 14-17 were short answer questions requiring the students to use some equations and electrical knowledge. We expected mixed results in this section due to the short amount of time we had to cover this material.

Exam II was graded out of 86 points. With problems 11, 12 and 13 being counted as bonus questions worth 5 points each, this was done after the fact, when it was realized that not to many of the students answered these problems correctly. The following is an examination of each individual problem on the exam.

Problem 1

The results of problem 1 were very good. Problem one was from Exam I. A little over 90% of the class got the correct answer, no surprise to us. The problem simply asked the students to identify the 3 subatomic particles of an atom and there charge, a very basic review question. Of the 3 students who got this all or part of this question wrong, one simply forgot to write the charge next to the particle. Another recorded an answer with nucleus-neutral instead of the neutron-neutral. Finally, the last reversed the charge on a proton with that of an electron.

Problem 2

Problem 2 was a labeling problem where the students matched a list of names with the appropriate part of the atom. It was identical to problem 2 on Exam I. The results of this question were nearly perfect. Again this was a very basic review question, we expect just about everyone to get this right.

Problem 3

Problem 3 required a little more thought, it was not on Exam I. We asked them what hold the protons together in the nucleus. The choices were: A. Electric Force, B. Strong Nuclear Force, C. Weak Nuclear Force, D. Ionic Bonding and E. Magic. This question required students to recall that the electric force is only the attraction of opposite charges and the repulsion of similar charges. Knowing that the nucleus contains only protons and neutrons and that protons have a positive charge and neutrons have a negative charge. The student should have realized that the electric force makes the protons repel each, so that is not the correct answer something else must be holding them together. Also the question mentioned that it is looking for a force so this rules out Ionic Bonding and Magic. Now the only two choices left are the strong and weak nuclear forces, this part required students to recall that it was the strong nuclear force. So naturally we expected in the results to find most of the answers either weak or strong nuclear force. This however was not so. Only 10 students (47%) got this question right with B. Strong Nuclear Force. Contrary to our prediction absolutely no one answered with the weak nuclear force. In fact 8 answered with the electric force and 3 answered with Ionic Bonding. This is very interesting. The students who answered with ionic bonding were most likely generally confused. It's hard to exactly tell what the students who answered with the electric force were thinking. Our educated guess says since practically everything we discussed in static electricity involved the electric force that naturally is the answer. On multiple choice tests student tend to not think. We hypothesize that if we first asked the students the effects of the electric force as a previous question that many would have realized that the electric force would be wrong because the protons would repel.

Problem 4

Problem 4 was straight from Exam I; we asked the students what sub atomic particles determine which element an atom is. The choices were: A. The color of the atom, B. The number of electrons, C. The number protons, D. The number of Neutrons and E. Both B & D. Only 11 students (53%) answered correctly with C. The number of protons. Eight students answered with E. Both B & D, the number of neutrons and electrons. As to why so many answered with the number of neutrons & electrons as the answer we are unsure. This was a big thing we emphasized when we taught the section on the atom. In Exam I when we asked what makes elements different from each other, either they responded with "the number of protons" or the number of protons and something else, so everyone had the number of protons somewhere in there answer along with nothing or something else.

Problem 5

Problem 5 was the first question that covered new material. We asked which answer best defined what current is. The choices were: A. The potential electric energy difference between two points, B. The flow of voltage through a material due to the electric force, C. The flow of electrons though a material due to some applied voltage, D. Amperes and E. Mickey Mouse. A total of 14 students (67%) got this correct with answer C. The remaining 7 students answered with B. We found this odd. We stressed the point that voltage does not move very clearly to the students. We must have repeated that current is the flow of electrons a couple hundred times and yet the students still got it wrong, we were disappointed with the results of this question.

Problem 6

Problem six asked the students which answer best defined what voltage is. The choices were: A. The flow of electron through a material due to some applied voltage, B. The potential electric energy difference between two points, C. Static electricity, D. Volts and E. Donald Duck. A total of 18 students (85%) got the correct answer B. Two students chose D. Volts, which is partially correct in that it is the units voltage is expressed in but we are looking for the best definition not units. One student was very confused and chose C. We were pleased with the results for this one but at the same time looking back to problem 5, those who may have gotten this question right still could have answered with B for number 5. Thus showing students were still confused as to what exactly voltage is. This is understandable because it is the hardest thing to visualize about electricity.

Problem 7

Problem 7 asked the students "A light bulb is an example of a?" and the choices were A. Resistor, B. Voltage Source, C. A Bright idea, D. A circuit element & E. Both A

& D. Thirteen students (62%) answered correctly with E. Five students answered with either A or D partial credit. In addition, out of left field three students answered with B. Voltage source. Answering A, D or E was expected but B was something that should have been obviously wrong. In the lab, we had the students calculate the resistance of a light bulb.

Problem 8

The results of problem 8 were not as good as we expected. The question asked students "A resistor does what?" the choices were: A. Opposes current flow, B. Opposes the Voltage, C. Conducts electrons very well and D. Both A & C. Fourteen students (66%) answered correctly with A. Opposes current flow. Two students answered with B. Opposes voltage, these students may have been thinking along the lines of voltage drops across the resistors. Two students chose C, completely wrong. These students defiantly did not have a good grasp of what was going on. Finally 3 students chose D two very conflicting answers. We wonder is we had simply rephrased A as Opposes *electron* flow if students would have picked D, because then it should have been defiantly obvious you can't opposes electron flow and conduct electrons very well. Number 8 should have been very easy.

Problem 9

The results from problem 9 were more encouraging, 15 students (76%) got it right by answering D. All of the above. We asked "a battery does what?", the choices were: A. Provides a constant voltage, B. Acts as an "electron pump" moving electrons from the + side to the – side, C. Transforms chemical energy into electric energy and D. All of the above. We noticed now that choice B may not have been worded that well. When we said "moving electrons from the + side to the – side" we meant *inside the battery*, some students may have thought that the electrons where being moved from the + side to the – side outside the battery through a wire or something, which is wrong. Thus causing students to out-rule D as a possible answer and making them have to choose between A or C which are both legitimate answers.

Problem 10

Nearly everyone got problem 10 correct. It was a simple matching problem. It asked the students to identify various circuit elements on the schematic, such as resistors in parallel & series, batteries etc.

Problem 11

Problem 11 was very abstract it required students to think about the equations and what they meant and apply them without the use of numbers. Only 4 students (19%) answered correctly with E. Due to the horrible results of this problem we tend to think that this was a lucky guess for the student who got it right. The results of this problem due make sense though if you look at the fact that student still had trouble with problems 5 & 6. The students were given a schematic of a simple battery hooked up to a resistor. The students were then asked what would happen if they placed another resistor in parallel with the resistor in the schematic. The choices were A. The voltage would increase and the resistance would decrease, B. The current would decrease and the voltage would remain the same, C. The resistance would decrease and the current would decrease, D. The current would remain the same and the resistance would decrease, E. The current would increase and the resistance would decrease & F. Both A and C.

The most popular response was B. This choice was a result of reasoning that if you ad a resistor the resistance increases, it's a very logical way of looking at it except that is only true for resistors in series. Not as many students as we liked made the connection that adding resistors in parallel actually decreases the total resistance contrary to what you would logically think. This is exactly why we added choice B.

Answer A ran against what just about everyone got right in problem 9. About 18 students (85%) answered problem 9 with either A or D. Choices A & D in Problem 9 stated that batteries provide a constant voltage. Choice A in problem 11 states that the voltage would increase this is contrary to the correct response in problem 9. We realize now that when teaching this class it was very easy to take for granted things we knew that were very basic, they didn't know. For example, in the circuit for problem 11 the voltage is a constant. Just little things like that make a problem seem easy to us, but are still hard for the students. Answer A however did state correctly that the resistance would decrease.

Three students answered with choice C. Choice C stated correctly that the resistance does decrease. However the current increases according to ohms law, it does not decrease. Students may have been thinking of the current through the added resistor, and may have known that it was less than that of the total current in the circuit. But we tend to think that they were probably just guessing. They have probably all heard by now "when in doubt circle C, it's the most common answer".

Choices D & F only received one answered each. Most likely these where guesses as well. Choice E, the correct answer only was chosen by 4 students half of which were probably guessing. If you look at the bonus points column on the Exam II scores table in

Appendix O, you can see 2 of the students who answered the bonus point question right, only had 49% and 47%, and the other 2 had 95%.

Problem 12

Problem 12 asked students to analyze the current through a circuit that contained 4 different resistors, two in series and two in parallel. The Choices were A. The same through each resistor, B. Each resistor will have a different current value, C. The current will be the same through R1 & R2, R3 & R4 will have different currents, D. The current will be the same through R3 & R4, R1 & R2 will have different currents. Only two students (9.5%) answered correctly with C.

The most popular answer winning with 9 was D. This was in there purposely to trip them up and it was a little too effective. In our lab we had them work with four 50ohm resistors placing various numbers of them in parallel and series. We think the students got too used to the idea that the current splits evenly between the parallel resistors, because of this. We don't think they thought it through enough that if different valued resistors are placed in parallel they will each have different currents. They just assumed it would split evenly and therefore D is the correct answer.

On the popularity charts choice B followed up choice D with 6 circled answers. Answer B seems very logistical to students. There are four different resistors therefore, four different currents. Unfortunately this only hold true for parallel resistors.

Choice A finished third with 4 students. Students may have taken the statement that "the current in a series circuit is the same everywhere" and applied it to this situation, either totally forgetting that this only applies to series. Or taken the fact that you can simplify the parallel resistors into 1 series resistor.

Problem 13

Problem 13 asked students to analyze the current through a circuit that contained 4 different resistors, two in series and two in parallel. The choices were A. The same everywhere, B. Different at every point, , C. The current will be different across R3 & R4, but the same across R1 & R2, D. Different across R1 & R2, But different across R3 & R4.

Choice A won the popular vote with 9 students. We were a bit stumped at first as to how this became the most common answer. We figure the students reasoned since the battery is fixed and that it pushes all the current in the circuit the voltage pushing the current must be the same everywhere. Next 7 students 19% responded with C, as the answer. Again this high response for C really stumped us. The best explanation is can provide was that kids just did not study form the exam. Answer D receives 4 votes total 19%. This was the correct answer. Only one student responded with choice B.

Problem 14

Problem 14 was the first of our short answer questions. The student simply had to know ohms law V=IR and be able to plug in the right values for the right variables. We gave them a simple circuit. A 10 volt battery hooked up to a 5ohm resistor. The question asked them to find the current. The students simply had to rearrange ohms law to I=V/R and plug in the given values and solve.

The results of problem were very good 19 student (90%) got it right. One person mislabeled the units and wrote 2 ohms instead of amps. Of the two students who go this question wrong, one mistook ohms law as I=VR instead of I=V/R and the other added the voltage and resistance together like the series resistance equation.

Problem 15

Problem 15 asked students to calculate two things, the equivalent resistance of 3 resistors in parallel & the current through the 2ohm resistor. This problem required students to first use the parallel resistor equation to find Req. Second student had to know which value to plug into ohms law to get the correct current value. Overall, 13 students (61%) got the equivalent resistance correct and 12 student (57%) got the current correct.

The calculating the equivalent resistance should was not the tricky part. It was simply plug and chug with the parallel resistance equation. We specifically told them the day before that they are going to need to know the equation for resistors in series and parallel and ohms law. Roughly 11 students had some rough mutation of the equation $1/R_{eq}=1/R_1+1/R_2+1/R_3$. It is very evident from the results that many students did not study the equations. Below are some common errors found on the exam.

$$R_{eq}=1/V+1/R_1+1/R_2+1/R_3$$
$$R_{eq}=1/R_1+1/R_2+1/R_3$$
$$1/R_{eq}=V/R_{eq}+R1/R_{eq}+R2/R_{eq}+R3/R_{eq}$$
$$1/R_{eq}=1/R_1+1/R_2+1/R_3=1/(R_1+R_2+R_3) \text{ so } R_{eq}=(R_1+R_2+R_3)$$

Problem 15 Common Errors

Calculating the current was not that hard. The trick was knowing which Voltage and resistance value to use. The most common mistake was the students used R_{eq} instead of 2ohms. Most students had I=V/R they simply used the wrong value.

Another contributing factor throughout these last 4 problems, though not as predominate was fractional math errors, stuff like students adding denominators together.

Problem 16

Problem 16 asked students to calculate the equivalent resistance and current of 3 resistors in series with a battery. This required the students to first calculate the equivalent resistance of the three resistors using the series equation. Then use ohm's law to calculate the current. Overall, 17 students (81%) calculated the equivalent resistance correctly and 14 students (66%) answered with the correct current value.

This problem was not as difficult as problem 15 and it showed with its higher score. Many of the same errors occurred, student just simply did not use the right equations. They needed to know three equations, Series Resistance, Parallel Resistance and Ohm's Law. If the students had simply been switching these 3 equations around and using them in the wrong places we would tend to think that the students were confused with the material. For the most part students just made up there own version of the equation. Only one or two students had the series and parallel equation switched around. The following are some of the error in equations we found.

$$I=VR$$
$$I=1/R1+1/R2+1/R3$$
$$1/R_{eq}=1/R_1+1/R_2+1/R_3$$
$$R_{eq}=R1*R2*R3$$
$$R_{eq}=1/R_1+1/R_2+1/R_3$$

Problem 16 Common Errors

Problem 17

Problem 17 asked students to calculate the equivalent resistance of a complex circuit containing parallel unit of 2 resistors in series with another resistor. The students were also given the current through this circuit and were asked to find the voltage of the battery. The students had to combine both the series and parallel equations in the right way to find the equivalent resistance. This was by far the hardest problem we gave them.

Problem 17 had an unusually large number of blank responses. This we linked to the fact that some student did have to leave early and possibly did not have the time to finish. Another because they just did not know how to approach this problem. Ten students (47%) answered the equivalent resistance correctly. Eleven students (52%) answered with the correct voltage, or at least used the right equation.

Many students did not calculate Req in two steps they simply combined both steps into one equation. Below are some of the more common mistakes.

$$V=R/I$$
$$Req=R1+1/R2+1/R3$$
$$Req = R1/I+R2/I+R3/I$$
$$Req=1/R1+1/R2+1/R3$$

Problem 17 Common Errors

Conclusions

This exam showed us that we might have rushed a little too much in the end. We also were able to see how varied the speed of learning is. Some students after only 2 days of the material were able to achieve perfect test scores while other in the class, we still confused about certain things. The grade distribution was fairly even ranging from 105 to 47 with clear divisions as to what would be an A, B, C, D, and F. This even distribution supports that the exam itself was a fair judge of the material that was learned. It shows that given a class with different abilities, there is destined to be differences in the grades that the students received.

Conclusion

"I liked the doughnuts"

In the beginning, we had a few difficulties to overcome; we were a little uncomfortable with presenting to the students, and standing in front of twenty-one prying eyes was a difficult task. This faded quickly as we stood out there and taught the lessons. The second difficulty that was encountered in the execution of this project was the presentation of the material. Not being trained as teachers, and being fairly far removed from the eighth grade level, we encountered great difficulty in gauging the amount of material that we could present to the students within a class period. Time in and time out, we came to class with about twice as much material as we ended up covering in a class period. Towards the end of the project, we were a little better at handling this, but time was running out which caused us to have to rush a bit.

The purpose of this project was to explore the effectiveness of different teaching methods with a group of students in physics. During the earlier stages of the project there was a fair period of time where we were adjusting to being on the other end of the classroom at such a different level. The fast pace at WPI for three years did not help us to meter the speed at which the classes should progress. For the few lessons, this was the area where the most development occurred. We did not have the ability initially to try different theories as we intended. Also it was required for us to cover some very basic background information that was not very interesting by it's very nature.

As time progressed, and we became more comfortable working with the students, we were better able to include some different styles of teaching including demos. The static electricity demos went over extremely well as was expected. The students really enjoyed them particularly when the Van De Graaff was used. Having the two of us go up and teach helped greatly when presenting to the students. Quite often, we would loose the students; it was visible in their facial expressions whether or not they understood, or at least following the material. With the two of us in front, when one was loosing the students, the other, being removed from the situation was able to easily step in and catch where the other fouled up and help to guide the students onto the proper path.

During the project, we generally presented to the material to the students in a manner where each of us will speak for a short duration and alternate, but for one of the lessons in particular we worked it so that each of us presented for half of the class. We both found this to make the presentation of material easier since we were able to get in a groove and just flow with the lesson plan. Another way we found to become more comfortable with resenting was that it was much easier to present material that you prepared for yourself. On some occasions, we would present material that the other person wrote. Teaching like all other aspects of life involves some amount of style, and if the style is not your own, or you are at least unfamiliar with the material, standing in front of the class and presenting will become a much more difficult task.

Peer Social Status

The classroom dynamics was one of the most interesting aspects of the project encountered through out its execution. The class was typical eighth-grade class composed of nearly equal numbers of males and females. The science department, unlike the math department does not track students, so there was a wide mix of abilities present within the class that we would be working with. This in itself made for some interesting correlations between our research and the actual project.

Typically during group activities, a few factors interfere with the success of the group learning exercise. The biggest impeding factors in group activities are the social status of the students coming into play in how the groups work progresses. In this class in particular, there were a few students whom where dubbed "the smart ones," often when they spoke, even if what they said was wrong, the other students would take it to be correct. Conversely, there were also the students that were also labeled as "the dumb ones" in the eyes of their peers. The latter case was much more frustrating from the teacher's point of view since we could observe one student in particular accepting their role, and not even putting effort into learning. Other times it was obvious that they were following the material, even understanding it, but could not take it further since they were almost giving upon themselves and their ability to learn.

Both of these cases came into play within the lab activity that the students had. The lab activity was to be a cooperative learning exercise where groups of students would first create a few different circuits and observe the affects that changing a few different parameters would have on the brightness of a light bulb. Once this part was done, they were to find some equivalent resistances using all 50-ohm resistors. Once they had this piece, the students were to try to find a relationship between voltage, resistance and current, Ohm's Law. The size of the classes was limited by the number of ammeters that were available to us to use with the students. This put three to for students together in a group.

The large size of the groups may have presented problems since many of the students were not participating so much as following along. The "smart ones" in groups would generally do most of the work while the others just followed along. In other cases, where the social status of the group was more homogonous, the group in general would work together to achieve the solution. In groups where there was a large split in the social status, the people whom were held as being of the least intelligence within the group would often not participate, or if they did participate, their suggestions might not be taken seriously by the other students.

In order to increase the effectiveness of group activities, the removal or at least reduction of the value of social status would be highly beneficial to all participants in the group activities. Possible ways to do this would be to get the students so involved in an activity that these thoughts move out of mind. To do this day in and day out is simply not feasible. Other ways would be to give each of the students enough responsibility; so that they would each have their own piece that they would work on at the same time. That way, each person will be forced to do their piece, and the feeling of their work being vital to the success of the group would still be present.

Capacity to Learn

Throughout the lessons, we consistently prepared more material that we used for that lesson. Gauging the student's capacity to learn was a difficult task. Perhaps observing the students more often with their normal teacher, a trained educator, we might have been better able to determine that amount of material that we could cover. Through our own experiences, by the end, we were able get near to the proper amount of material, however there were still problems with the type of material that we could cover.

Going in only twice a week, amidst their regular physical science class schedule did not help to make matters any easier to cover material. While several continuous weeks of lessons would have probably facilitated their learning of our material, it was simply not feasible since the material that we were covering was not necessarily in their curriculum, and missing the other material would interfere with their regular class work.

Generally, material that was to abstract to the students would loose them. Cases where we repeatedly lost the students were when we would attempt to explain things using specific numbers or units of measurement that they were not familiar with. This inability to tie the abstract thoughts to their previous knowledge was very evident. Bits of knowledge that we take for granted as juniors in an engineering university, were not even present in the minds of the eighth grade students. This seems to be the key to getting through to the students, relating what we were presenting to what they already know.

The laboratory exercise brought the most insight into how the students learned. By its very nature, a laboratory exercise provides a more interesting avenue for the students to pursue knowledge. Lab activities offer a break from the normal lecture type of lesson, and provide the students with an opportunity to gain some concrete evidence to support their learning. In working with the physical, the students are able to link the knowledge with the actual experience that they had. The limitations that were encountered, as described earlier did limit the effectiveness that the laboratory exercises had in assisting the learning of the students. If a student actively participates within the lab, then the quality of the learning exercise would be greatly enhanced when compared to a student that just followed along, or copied off their peers.

The use of different demonstrations definitely enhanced the students ability to take in information. With the static electricity demos in particular, we had a very positive response from the students, and while some of the demos, such as the shock ring, did not offer that much information to the students, the simple fact that they were getting up and actively participating in an activity got them excited, and made them more ready to learn.

Possible improvements

The biggest room for improvement would have been obtaining a better understanding of how much and quickly the students can learn at that level. Initially we had planned to go in and sit in on a lesson, but as things progressed, the only opportunity that we had to go in was during a lab, so we were unable to see exactly how much of what was being taught. Observing their normal teacher instructing them in a typical lesson would have been quite beneficial for determining the amount of material that could be covered in a class period. The difficulty with this of course is that all classes are going to be different, so try as best as possible to how well the learning will proceed at the grade level, and what material the students had covered earlier.

In our Basic atomic structure, pretest there was a comment to the extent of the 5th grade science class had covered similar material. Yet many of the students were unable to answer many of the questions on the pre test, they did fairly well on the post test, but then again on the cumulative final, they did not always do so well on the parts that covered the earlier material. Gaining a greater amount of material as far as the curriculum from the earlier grade levels would be useful, however it would be near to impossible to determine how much of the material the students would retain. In this aspect is essential not to assume that the students know anything. If the students as a whole are very familiar with the material you are covering, it will become obvious through their facial expressions, which would signal one to move through it faster.

The biggest complaint that the students had was the pace of class. Consistently in the reviews, there were comments about slowing down. The reasons for our fast pace were based in several underlying factors. The biggest was the time constraint that we faced, we had only five weeks of teaching, and the limitations put upon us by the time constraints were worsened by the ambitious amount of material that we planned to present to the students. Being realistic in the amount of material that will be covered, and how much time would be required is essential to achieving success with a project in education.

With the lab, in particular several different areas for improvements were quite evident. The lab activity had the students in groups of 3-5 due to the number of ammeters that we had. Groups with three worked fairly well, however groups any larger were a little too chaotic. In addition, there were some assumptions made as to how the students would complete the lab. In order to get the material that you are looking for it is essential that you explicitly request it from the students, and lay out the activities for them step by step. During the lab activities, many of the groups strayed far from the intent of the lab and embarked on experimentation of their own. While the learning may have occurred with the self-experimentation, the unguided exploration resulted in the destruction of a couple of the antiquated ammeters that we were using. It also prolonged the duration of the lab activity and caused it to take up an additional day.

Final thoughts

The material that we presented to the students was of a much higher level then they would have normally been exposed to at the eighth grade level. While we often lost them in the lectures, the results of the test scores supported the fact that at least a few of the students retained the information that we presented to them. Given the short duration of our lessons with the students and the complexity of what we had been presenting to them, we found this to be encouraging. Given enough time, it would have been simple to get all of the students to work at the level that we had planned if given enough time. Current curriculum and educational standards however have the students learning at a level that is fairly far bellow what they are capable and perhaps where they should be.

Would an updated science education curriculum help to secure the United States as a leader in the technology race? It could not hurt; familiarity with things helps people to become more comfortable when working with them. If elementary education had a more technologically biased base to it, naturally the students completing that part would be more likely to thrive in a society where technology plays an important part in daily life.

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Useful Resources

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Useful Web Resources

All were current as of completion of this project April 2001

Adprima: provides logistical information about all aspects of teaching to teachers and teachers to be. We found the parts on lesson planning particularly useful.
http://www.adprima.com/

Teach to Prime: List of behavioral verbs, came up in a search engine. Used in forming lesson plans.
http://members.spree.com/teach2prime/verbs.htm

The Physics 163 Page: Provided background information on some physics relates stuff that we were a little rusty on, particularly the sections on static electricity.
http://www.glenbrook.k12.il.us/gbssci/phys/p163/u8help.html

A Science Odyssey: Information about the atom was found here, also has a neat little shockwave atom builder that we were going to have the students play with.
http://www.pbs.org/wgbh/aso/tryit/atom/

A brief explanation of atomic structure and electrical conduction: Pretty self-explanatory. Created by a student in teaching.
http://www.mste.uiuc.edu/murphy/HoleFlow/Structure.html

Electronics in Schools Christchurch Polytechnic: More useful background information found here particularly dealing with atomic structure and conductance.
http://courseweb.chchpoly.ac.nz:8081/eis/intro/default.htm

VDG Hints and Demos: Some cool Van De Graaff demos.
http://www.amasci.com/emotor/danc

Voltage: Provided a lot of background information on electricity. We used this in trying to build up the foundation of the student's understandings of electricity.
http://learn.western.tec.wi.us/circuit/Cffs/cf1/cf1unit2/VCRsep.html

Appendices

"I think they would make the perfect team one day. They are both nice and caring. If we needed help they were there helping us."

Appendix A: Preliminary Interest Survey

Science Class Interest Survey

1) Is there anything that you would like to learn more about related to science? Pleases circle as many as apply

Motion	Electricity	Sound Waves	Heat
Energy	Magnetism	Light Waves	Other____________

2) If given the chance, what would you do to make science class time more interesting?

3) Has there been a particular class or demonstration that you found to be very interesting?

4) Do you like science class? Explain why.

5) Do you ever have trouble paying attention in class?

6) Do you like to work in groups or individually?

7) Do you think a group science competition would make class more fun and interesting?

8) Do you enjoy lab activities? If no, what could be done to make them better?

Appendix B: Behavioral Verbs.

Behavioral Verbs

Behavioral verbs are the heart of learning objectives. They are, if used effectively, the best way to indicate, and communicate to others, specific, **observable** student behavior. Behavioral verbs describe an **observable** product or action. Inferences about student learning can be made on the basis of what a student does or produces. The following verbs and their definitions can be helpful when composing behavioral objectives. These are general definitions that describe only the **observable** behavior and do not include linkages to any specific content.

APPLY A RULE: To state a rule as it applies to a situation, object or event that is being analyzed. The statement must convey analysis of a problem situation and/or its solution, together with the name or statement of the rule that was applied.

CLASSIFY: To place objects, words, or situations into categories according to defined criteria for each category. The criteria must be made known to the student.

COMPOSE: To formulate a written composition in written, spoken, musical or artistic form.

CONSTRUCT: To make a drawing, structure, or model that identifies a designated object or set of conditions.

DEFINE: To stipulate the requirements for inclusion of an object, word, or situation in a category or class. Elements of one or both of the following must be included: (1) The characteristics of the words, objects, or situations that are included in the class or category. (2) The characteristics of the words, objects, or situations that are excluded in the class or category. To define is to set up criteria for classification.

DEMONSTRATE: The student performs the operations necessary for the application of an instrument, model, device, or implement. NOTE: There is a temptation to use demonstrate in objectives such as, "the student will demonstrate his knowledge of vowel sounds." As the verb is defined, this is improper use of it.

DESCRIBE: TO name all of the necessary categories of objects, object properties, or event properties that are relevant to the description of a designated situation. The objective is of the form, "The student will describe this order, object, or event," and does not limit the categories that may be used in mentioning them. Specific or categorical limitations, if any, are to be given in the performance standards of each objective.

DIAGRAM: To construct a drawing with labels and with a specified organization or structure to demonstrate knowledge of that organization or structure. Graphic charting and mapping are types of diagramming, and these terms maybe used where more exact communication of the structure of the situation and response is desired.

DISTINGUISH: To identify under conditions when only two contrasting identifications are involved for each response.

ESTIMATE: To assess the dimension of an object, series of objects, event or condition without applying a standard scale or measuring device. Logical techniques of estimation, such as are involved in mathematical interpolation, may be used. See MEASURE.

EVALUATE: To classify objects, situations, people, conditions, etc., according to defined criteria of quality. Indication of quality must be given in the defined criteria of each class category. Evaluation differs from general classification only in this respect.

IDENTIFY: To indicate the selection of an object of a class in response to its class name, by pointing, picking up, underlining, marking, or other responses.

INTERPRET: To translate information from observation, charts, tables, graphs, and written material in a verifiable manner.

LOCATE: To stipulate the position of an object, place, or event in relation to other specified objects, places, or events. Ideational guides to location such as grids, order arrangements and time may be used to describe location. Note: Locate is not to be confused with IDENTIFY.

MEASURE: To apply a standard scale or measuring device to an object, series of objects, events, or conditions, according to practices accepted by those who are skilled in the use of the device or scale.

NAME: To supply the correct name, in oral or written form for an object, class of objects, persons, places, conditions, or events which are pointed out or described.

ORDER: To arrange two or more objects or events in accordance with stated criteria.

PREDICT: To use a rule or principle to predict an outcome or to infer some consequence. It is not necessary that the rule or principle be stated.

REPRODUCE: To imitate or copy an action, construction, or object that is presented.

SOLVE: To effect a solution to a given problem, in writing or orally. The problem solution must contain all the elements required for the requested solution, and may contain extraneous elements that are not required for solution. The problem must be posed in such a way that the student that the student is able to determine the type of response that is acceptable.

STATE A RULE: To make a statement that conveys the meaning of the rule, theory or principle.

TRANSLATE: To transcribe one symbolic form to another of the same or similar meaning

http://members.spree.com/teach2prime/verbs.htm

Appendix C: Lesson 1, Basic Atomic Theory

Lesson 1: Basic Atomic Theory

March 14,2001

Purpose: The main purpose of this lesson is to build a basic understanding of the atom so that we can move on to electricity. We will first cover atomic structure, the composition of matter, valence shells, and the effect that these have on a materials ability to conduct electricity.

Objectives: To define what an atom is to the students, and to illustrate the different pieces of the atom. To show the students how matter is composed of atoms, and the difference between elements and compounds. To demonstrate the Bohr atomic model, and show how atomic structure affects materials insulating properties. For us to gain some experience with teaching and to become more comfortable teaching the students.

Behavioral Objectives: Behavioral objectives are descriptions of observable student behavior, or performance that are related to learning. We will use these not only to meter the performance of the students, but as part of the evaluation of our effectiveness. The italicized words are verbs from the behavioral verbs lists used for lesson plan development.

1. For the students to be able to *define* what an atom is and *identify* the sub-atomic particles.
2. The students shall identify the charge of each of the sub atomic particles.
3. For the students to be able to *describe* the make up of matter, and *distinguish* between elements and compounds.
4. Given the atomic number, and atomic mass the students shall be able to *calculate* the number of protons and electrons.
5. For the students to be able to *construct* a diagram of the Bohr atomic model the atomic structure of some number of elements.
6. For the students to be able to identify what forces keep the atom together
7. *Understand* that ions are atoms of a particular element that have given up or received electrons in order to form bonds with other elements.
8. The students, upon completion of this lesson should be able to *predict* whether a material will make a good conductor or insulator

Criteria: The Criteria corresponds with the behavioral objectives above, and represents a minimum amount of the behavioral objectives that must be demonstrated in order to consider the material to be understood by the students, and in our case, our teaching to be effective.

1. The student should include in their definition of the atom that it is the building block of mater and identify that it is made up of protons, neutrons, and electrons.

2. The students will identify that protons are positive, electrons are negative and neutrons are neutral.
3. The students should be able to say that all matter is composed out of atoms, and that elements are made up of one type of atom where as compounds are made up of different types of atoms.
4. The students should understand that the number of electrons is the same as the number of protons for a neutrally charged atom, and that the number of neutrons is equal to the atomic mass minus the atomic number.
5. The students shall be able to construct a Bohr atomic model and properly place the protons, neutrons, and electrons for a variety of different atomic configurations including ions.
6. Based on the Bohr atomic models that are made, the students should be able to make some more general predications about the electrical behavior of the materials given to them.

Procedure: We will start off the class, by introducing ourselves, and letting the students know why we are there. We will then proceed to distribute the pre test covering the basics of atomic structure. We will sit, answer any questions, and generally be available to the students during this stage. Talk about how the survey said that most of the students were interested in learning about electricity, so we were going to cover some basics, before we went into static electricity, and then into regular electricity.

1. *Does any one here know what an atom is?* -- An atom is the fundamental building block of all matter. It is the smallest piece of any given material that still retains all of that material's properties.

2. Elements are materials that are made up of only one type of atom. If one were able to take an element (re-stress that elements are only made of one type of atom) like gold for example, and slice it up into halves, again and again and again, then eventually the smallest particle that you would come up with that is still gold is the atom, of course we know that this isn't necessarily practical, but the main thing to remember is that the atom is the smallest pieces of mater that still retain the same properties as the pure element. (3Min)

3. *What would we get if we were able to cut that final atom into smaller pieces?* – If we were able to cut the atom into pieces, we would most likely come up with the nucleus and the electrons that surround the electron, (sketch image of atom)

4. Atoms are made up of three smaller parts, the protons, and neutrons, which form the nucleus, and the electrons that surround the nucleus. (6Min)

5. To try to give you idea of the scaling of the atom, it the nucleus were as big around as a strand of hair, then the atom itself would be approximately six and a half feet around. We know that since the electrons are smaller then the protons, this would mean that the atom itself is made up mostly of empty space. The outside diameter of an atom is approximately 10,000 times that of the nucleus.

6. The electrons are kept around the nucleus by an electric force, because we know that bodies of opposite charge are always attracted and bodies of similar charge repel. *What keeps the nucleus together? Would it not seem that the nucleus should fly apart since it is made up of all protons, and neutrons, which have the same or no charge at all?* Well luckily for us the world will not be flying apart anytime soon because we have the strong nuclear force that holds the nucleus together. The strong nuclear force is much stronger than the electric force but only at a short range which does not extend much father than the nucleus.

7. Once formed into their atoms, except for under <u>special circumstances</u>, the protons, and neutrons (nucleus), cannot be moved apart. This is because of the Strong atomic force that holds them together. The only time when the nucleus is allowed to come apart is during nuclear reactions, when there is a tremendous amount of energy released, in the form of heat, as in nuclear reactors, and as explosions, in the case of atomic bombs.

8. Electrons on the other hand, are allowed to move between different atoms more easily. Electrons can move between different valence shells and other

atoms when given enough energy. Electrons often move around in various situations, including bonding (give example of salt), the molecular composition of materials (metals—sea of electrons), and differences in electrical charge (lightning, static, current electricity).

9. Periodic table of elements, (overhead of periodic table would be good here), show the meaning of the numbers on the periodic table, the atomic mass is the weight of the atom in *amu*, and what an *amu* is, *amu* = 1.67*10^-27 kg. The atomic number is the number of protons that are located in an atom of a particular element.

    a. Make Oxygen (8/16) atom on board, see if students understand what you did to draw the representation of the atom.
    b. Have the students create a drawing of the Beryllium (4/9) atom in the little blue book.

10. Show that the number of protons is what determines what a particular atom is made with. Show how charges would denote different ions of a particular material.
    a. Make Oxygen atom into negative Ion.
    b. Have Students make a $Hydrogen^{+}$ Ion.

11. Brief discussion of valence shells and how they affect the conductance of materials. Valence shells are the outermost shells, and as a result of this, the electrons there don't have as much force holding them together with the rest of the atom when compared to the more inner shells. Conductors have fewer electrons in their valence shells, usually one to two, where as insulators usually have five or more. If an electron can gather enough energy, the electrons can break free and move through out the material. In materials such as copper there is enough heat energy at room temperature to break some electrons free.

12. Explain that there is not always whole numbers for the atomic mass since it is the average of the atomic masses of elements. If the number of neutrons is equal to the atomic mass minus the atomic number, for some elements, we get not whole numbers.-- How can this be? --. Are there parts of neutrons present in these elements? Explain, as you did slightly earlier that the atomic mass is an average number, so since each element must have the same number of protons, there would have to be different numbers of neutrons some times, explain, that this is an isotope, and name the common, carbon 14, carbon 12 etc. . . .

Appendix D: Letter to Parents

Dear Parents of Ms Petit's Eight Grade Science Class,

Hello, our names are Christopher Knight and Joshua Engstrom; we are third year students at Worcester Polytechnic Institute. As a part of the WPI plan, we are required to complete three projects. The Interactive Qualifying Project (IQP) challenges students to identify, investigate, and report on a self-selected topic examining how science or technology interacts with societal structures and values. The objective of the IQP is to enable WPI graduates to understand, as citizens and as professionals, how their careers will affect the larger society of which they are part.

Our IQP deals mainly with the implementation of a program that will inspire and stimulate the 8th grade students in the area of physics. Particularly our program will contain a cooperative, hands on unit that involves electricity, an area of science where the students expressed the most interest. We will come to class twice a week to instruct your children. In general the material taught will be more in-depth then would normally be covered at this level however it will not affect the students grades. Thank you, and if you have any concerns or questions email Christopher Knight at sirk@wpi.edu.

Sincerely,

Joshua Engstrom

Christopher Knight

Appendix E: Pre-Test for Atomic Structure

Name:____________________

Pre Survey
Basic Atomic Theory

1. Explain what you think an atom is? Write down anything you can think of. (hint: what particles make up an atom)

2. Sketch what you think and atom looks like. Label as much as you can.

3. What do think makes atoms different from each other?

4. Write down anything specific you wish to learn about electricity.

Appendix F: Lesson 2, Intro to Electrostatics

Lesson 2: Basic Atomic Theory and Intro to Electrostatics

P.O.A.: March 15, 2001

Purpose: The main purpose of this lesson is to review the basic material of the atom so that we can move on to electricity. To begin the electrostatics section, which will ultimately lead into our unit on electricity.

Objectives: To reinforce the information about the atom that we presented to the students on the previous day, and start into electrostatics, the next section of the lessons that we will be covering.

Behavioral Objectives: Behavioral objectives are descriptions of observable student behavior, or performance that are related to learning. We will use these not only to meter the performance of the students, but as part of the evaluation of our effectiveness. The italicized words are verbs from the behavioral verbs lists used for lesson plan development.

1. For the students to be able to meet the behavioral objectives set forth in the first lesson, particularly around the atom.
2. The students should be able to *describe* the difference between a molecule and an atom.
3. For the students to be able to *describe* what electrical charge is and how that charge will behave.
4. Given some circumstances, a student should be able to *predict* how the charge will move through a system.
5. They should be able to *identify* the charge of a body given a set of conditions.
6. *State* the fundamental Law of conservation of charge

Criteria: The Criteria corresponds with the behavioral objectives above, and represents a minimum amount of the behavioral objectives that must be demonstrated in order to consider the material to be understood by the students, and in our case, our teaching to be effective.

7. The student should be able to meet the criteria from lesson one.
8. The students should be able to distinguish from an atom, ion, or molecule.
9. The students will be given a worksheet that has a few different charge transfer scenarios on which they should be able to predict the charge distribution through out the system in the various stages.
10. Given a body with some charge distribution the student should be able to identify the charge of the object.
11. The students should understand that transfer of charge occurs via the movement of electrons.

To start the class: Draw an aluminum atom on the board with the nucleus as a circle with the label (13 protons), with energy levels 2 in first 8 in second 3 in the outside, have the students name features for tootsie roll. We will ask the following questions:

1. Can anyone point out what is the Nucleus?
    a. Obvious?
2. How many electrons are in the outermost valence shell?
    a. Come on now?
3. What charges do each of the sub-atomic particles have?
    a. Josh you should know this!
4. With that in mind, what properties would we expect, would this material be more of a conductor or an insulator?
    a. Conductor
5. Can anyone identify what element this is?
    a. Aluminum
6. How many neutrons should be drawn on the board?
    a. 14 Neutrons
7. What force is keeping the electrons around the nucleus?
    a. Electric Force

We will then remove an electron from the outermost valence shell and ask: What will be the charge of this atom now? (AL^{+1}) This is what we would call an **Ion**.

> **Ion:** An atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons.
>
> **Free electron:** An electron

Draw a molecule of NaCl (salt) show that it is made up of Na^{+1} and Cl^{-1} ions, and that because they each have an equal and opposite charges they stick together. This is known as an Ionic bond because it is formed between the ions in the compound.

> **Molecule:** The smallest particle into which a compound can be divided without changing its chemical and physical properties; a group of like or different atoms held together by chemical bonds.

Electrical charge: Electrical charge is one of the fundamental properties/attributes of these particles, protons carry a positive charge, electrons carry a negative charge and neutrons, much as the name implies are neutral.

Paradox: When dealing with electric charge, it is possible to describe the behavior and properties, but it isn't possible to say exactly what it is. It is not always important to know that knowing exactly what something is, but the ability to observe something and make predictions about it is.

Take gravity for example, we all know what it is, but what is it? – We can feel it acting on us all of the time. We can feel the affects of it, you have done with calculations with it, but at the same time, we can't say exactly what it is. This is all good because it isn't necessary to know exactly what causes gravity, just the effect that it has on the things around us. Electric charge is very similar in that sense.

Meat and potatoes: Electrostatics deals primarily with imbalances of electrical charge at or near rest. Since electrical charge is based on the movement of electrons, we can say that it is **quantized** -- meaning that it can only have whole values of charge. An analogy to this would be money, where each electron would a penny, and in normal transactions, there is never any amount of money less then a cent.

-A body can gain a charge by transferring charge with another body

-A structure that is said to have a negative charge if there is a surplus of negative charges located within this body

-Negative charge is obtained either by a gain of negative charge or a removal of positive charge.

-Conversely a body is said to have a negative charge if there is a surplus of positive charge located within the structure.

-Similarly positive charge is obtained either through the addition of positive charge or the removal of negative charge

-In most cases, we deal with the movement of negative charges; since electrons are negatively charged and are highly mobile. Thus bodies with a positive charge generally are bodies that have lost some negative charge.

Fundamental Law of Conservation of Charge: For any closed system the total amount of charge will remain the same.

-In the case of rubbing a balloon on your head, the balloon picks up a negative charge where as the loss of the negative charge in your hair gives your hair a positive charge, but the sum of the charges is still the same.

-When lightning strikes the earth, the entire earth or at least that area of the earth would be considered the closed system, and the net charge would always remain the same, zero.

-Generally we refer to the earth as Ground, since in it's immense size the earth is able to absorb a large amount of charge and disperse it.

-Materials that are said to be uncharged are actually of a neutral charge, there is and equal amount of positive and negative charge.

Transfer of charge of charge can occur in a few different methods

-**<u>Conduction</u>**, conduction is the direct transfer of charge due to contact between the different bodies.

-The most common example of this is when you attempt to touch a doorknob after walking across a carpeted floor in the winter, when your hand is in direct contact with the metal object, there is a transfer of electrical charge in the form of a spark.

-A common misconception is that charge can be transferred via friction, such as the case of rubbing a balloon on your head, or walking across the carpet and the charge that you acquire thought that action. In fact, this transfer occurs due to the molecular bonds that are formed between the objects, and those bonds that are broken, when objects are separated. The breaking of bonds upsets the numbers of electrons that were present.

-This type of transfer is better named **<u>contact charging or electrification</u>** to avoid the confusion, that the friction another effect of surface contact is a factor which controls the electrification

-Through experimentation, scientists have developed the triboelectric chart, a method of determining the type of charge that a material will gain through contact with other objects.

-**<u>Induction</u>** is the phenomenon that objects that are in close proximity, primarily induction deals with the rearrangement of the charges within a body.

-Induction can occur with both insulators and conductors.

The valence shell is the outermost shell in an atom
A free electron is one which has broken away from the valence shell of its parent atom
A positive ion is produced when a parent atom loses an electron
Electrical conduction is the flow of free electrical charge through a material
A good conductor contains a large number of free electrons
Metals are typically good conductors
Copper is a commonly used conductor in the electrical and electronic industries
Insulators are poor conductors of electricity
Insulator produces few free electrons
Some insulators are Polyvinyl chloride (PVC), Polycarbonate, Rubber compounds, Ceramics, Glass, Air, Oil
Van De Graaff – Produces negative charge by creating an abundance of negative charge in the base, and transferring through conduction, via a metal comb to the rubber belt. Since rubber is an insulator, the charge cannot move freely through it, so the motor to the top where another metal comb picks up the negative charge and disperses it through out the metal sphere carries it. The metal sphere serves to store the electrical charge.

Balloon, attracts first through induction, then after contact conduction puts more negative charge onto the balloon and they repel.

Hair (obviously)

Charge electroscope induce charge on sphere – ground – test charge

Shock ring

Appendix G: Lesson 3, Electrostatics

Lesson 3: Electrostatics

P.O.A.: March 21, 2001

Purpose: To move more deeply into the electrostatics section, which will ultimately lead into our unit on electricity. During this class we decided that no matter where we were would, with about 15 minutes left we would move to the Van De Graaff demos, since we had taunted them with the Van De Graaff being there and unused the day before.

Objectives: Cover the bulk of the material on electrostatics. To get the kids interested in the material that we will be covering and to have a successful day of teaching.

Behavioral Objectives: Continued from last lesson.

Criteria: Continuation of last lesson

To start the class: We will say, and today we are going to pick up where we left off last time in our discussion about static electricity.

Chris---

Electroscope: Helps to determine if an object is charged, and with some procedure can be used to determine the charge of an object. **Draw (Josh)** diagram on the board of the particular electroscope that we will be using.

Chris demos the electroscope

1. **First charge very negative, and ground to show how ground is used**
2. **Charge slightly negative, then use the positive charge to show how we can determine charge of objects with known charge**
3. **Charge positively and use a slightly negative charge to show the reverse of 2.**

Josh---

-**Contact Charging** A common misconception is that charge can be transferred via friction, such as the case of rubbing a balloon on your head, or walking across the carpet and the charge that you acquire thought that action. In fact, this transfer occurs due to the molecular bonds that are formed between the objects, and those bonds that are broken, when objects are separated. The breaking of bonds upsets the numbers of electrons that were present.

Chris draws before and after of charging the plastic rod with rabbits fir, or one with little arrows to show the charge moving.

-This type of transfer is better named **contact charging or electrification** to avoid the confusion, that the friction another effect of surface contact is a factor which controls the electrification

-Describe grounding, and what is happening to the system.

-Describe very briefly that one of objects has a higher affinity for electrons meaning "likes them more" and that object, through contact will strip away electrons from the other material.

Demo for contact charging (Chris): Charge plastic rod with rabbits fur discharge on the electroscope, show that the pin moves because it is repulsed by the like charges. Next, ground the electroscope. Repeat with silk and glass rod.

Chris--

-**Conduction**, conduction is the direct transfer of charge due to contact between the different bodies.

-The most common example of this is when you attempt to touch a doorknob after walking across a carpeted floor in the winter, when your hand is in direct contact with the metal object, there is a transfer of electrical charge in the form of a spark.

-Say this is what happens when the rod is touched to the electroscope.

-Induction is the phenomenon that objects that are in close proximity, primarily induction deals with the rearrangement of the charges within a body.

-Induction can occur with both insulators and conductors.

Make a drawing of two spheres inducing a change

Demo for induction (Josh): Using rabbit's fir, plastic rod, electroscope, the chicken stick and one of the small spheres, first induce a charge into the sphere, next ground it. Use the sphere to charge the electroscope. Next ask the class--Can any one tell me how we can determine the charge of the electroscope? Say "well since we were trying to induce a charge (have drawing on board of induction) we will assume that we have a positive charge, so by charging this rod negatively, since it would be the opposite of the positively charged electroscope, the pointer will attract itself to the rest of the electroscope.

Worksheet: Repeat appropriate demos for the worksheet, have the students hypothisize with the promise of candy.

Van De Graaff – Produces negative charge by creating an abundance of negative charge in the base, and transferring through conduction, via a metal comb to the rubber belt. Since rubber is an insulator, the charge cannot move freely through it, so the motor to the top where another metal comb picks up the negative charge and disperses it through out the metal sphere carries it. The metal sphere serves to store the electrical charge.

Balloon, attracts first through induction, then after contact conduction puts more negative charge onto the balloon and they repel.

Hair (obviously)

Charge electroscope induce charge on sphere – ground – test charge

Shock ring

Appendix H: Lesson 4, Transfer of Static-Charge

Lesson 3: Electrostatics

P.O.A.: March 22, 2001

Purpose: To move more deeply into the electrostatics section, which will ultimately lead into our unit on electricity. To use the Van De Graaff for demonstrations puposes and to go through with the students a worksheet that we will be providing them dealing with the transfer of charge..

Objectives: To cover the specifics of charge transfer, coincidently to try our skills with winging it (this is basically the same material that we covered the day before so we didn't come up with a new lesson plan.

Behavioral Objectives: Continued from last lesson.

Criteria: Continuation of last lesson

To start the class: We will say, and today we are going to pick up where we left off last time in our discussion about static electricity.

Josh--

-**Contact Charging** A common misconception is that charge can be transferred via friction, such as the case of rubbing a balloon on your head, or walking across the carpet and the charge that you acquire thought that action. In fact, this transfer occurs due to the molecular bonds that are formed between the objects, and those bonds that are broken, when objects are separated. The breaking of bonds upsets the numbers of electrons that were present.

Chris draws before and after of charging the plastic rod with rabbits fir, or one with little arrows to show the charge moving.

-This type of transfer is better named **contact charging or electrification** to avoid the confusion, that the friction another effect of surface contact is a factor which controls the electrification

-Describe grounding, and what is happening to the system.

-Describe very briefly that one of objects has a higher affinity for electrons meaning "likes them more" and that object, through contact will strip away electrons from the other material.

Demo for contact charging (Chris): Charge plastic rod with rabbits fur discharge on the electroscope, show that the pin moves because it is repulsed by the like charges. Next, ground the electroscope. Repeat with silk and glass rod.

Chris---

-**<u>Conduction</u>**, conduction is the direct transfer of charge due to contact between the different bodies.

-The most common example of this is when you attempt to touch a doorknob after walking across a carpeted floor in the winter, when your hand is in direct contact with the metal object, there is a transfer of electrical charge in the form of a spark.

-Say this is what happens when the rod is touched to the electroscope.

-<u>Induction</u> is the phenomenon that objects that are in close proximity, primarily induction deals with the rearrangement of the charges within a body.

-Induction can occur with both insulators and conductors.

Make a drawing of two spheres inducing a change

Demo for induction (Josh): Using rabbit's fir, plastic rod, electroscope, the chicken stick and one of the small spheres, first induce a charge into the sphere, next ground it. Use the sphere to charge the electroscope. Next ask the class--Can any one tell me how we can determine the charge of the electroscope? Say "well since we were trying to induce a charge (have drawing on board of induction) we will assume that we have a positive charge, so by charging this rod negatively, since it would be the opposite of the positively charged electroscope, the pointer will attract itself to the rest of the electroscope.

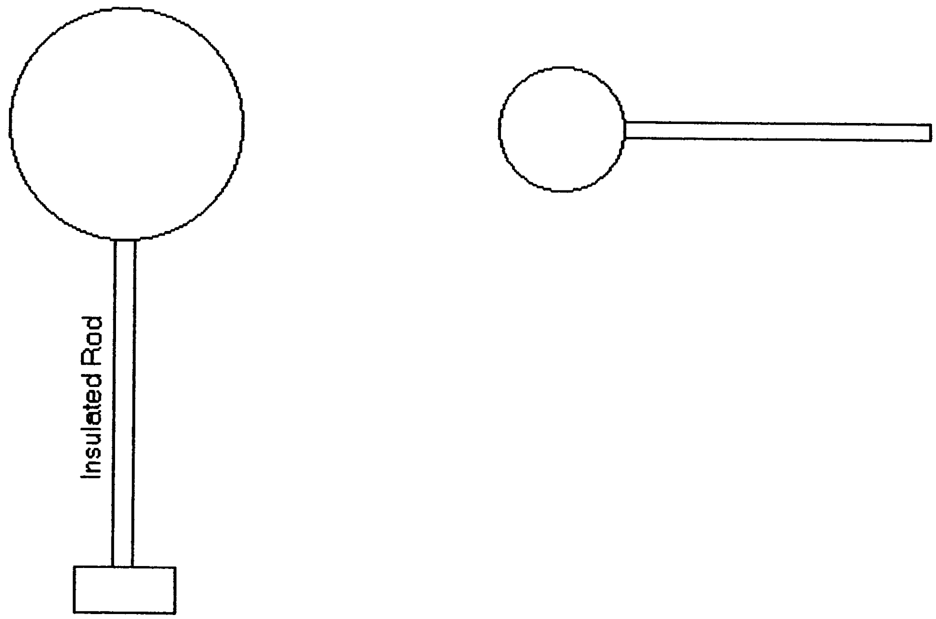
Worksheet: Repeat appropriate demos for the worksheet, have the students hypothisize with the promise of candy.

Go through worksheet by asking, have students come up and do the demo with us.

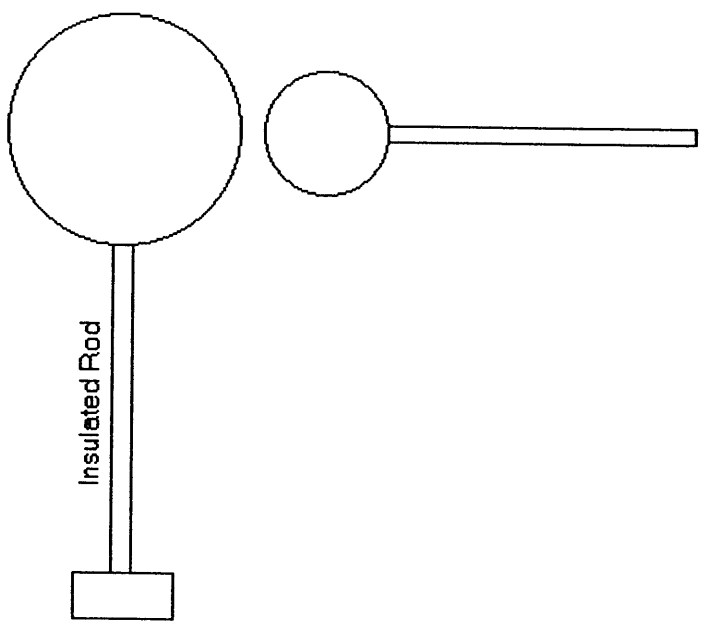
Name:_______________
WKS 1

CONDUCTION CHARGING

1



2



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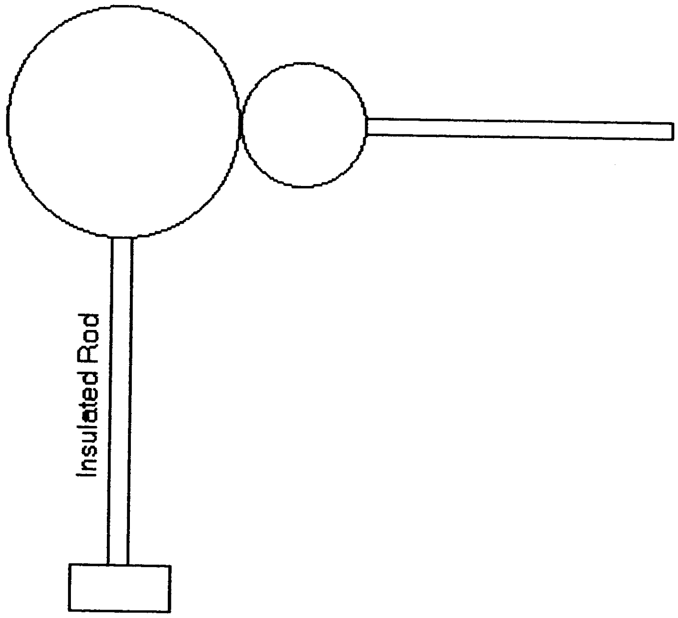

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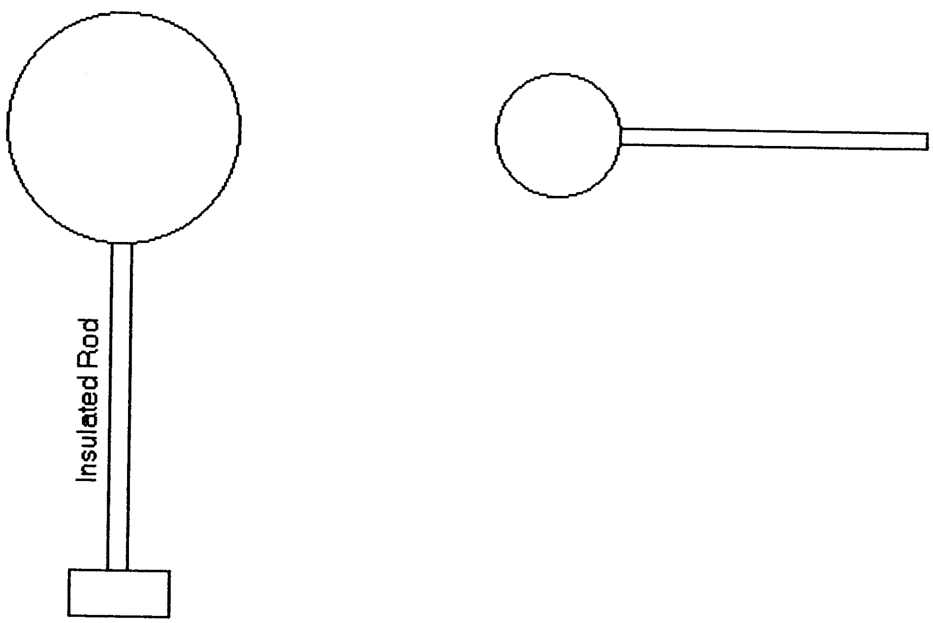
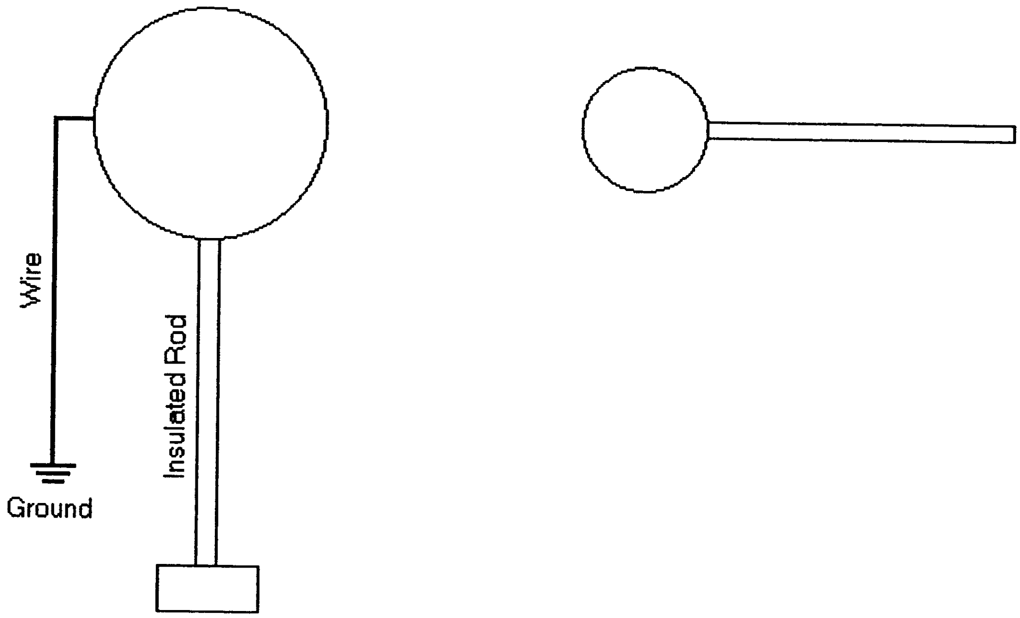


INDUCTION CHARGING

1



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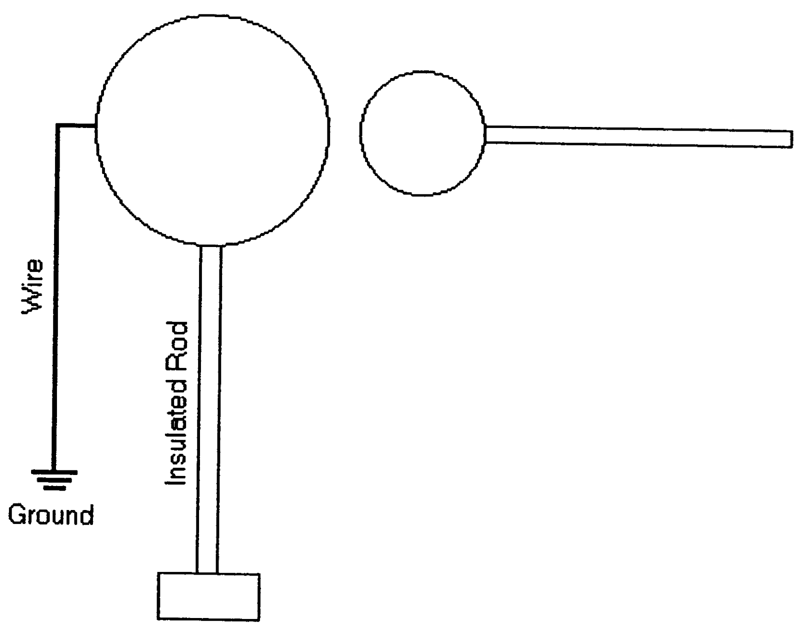

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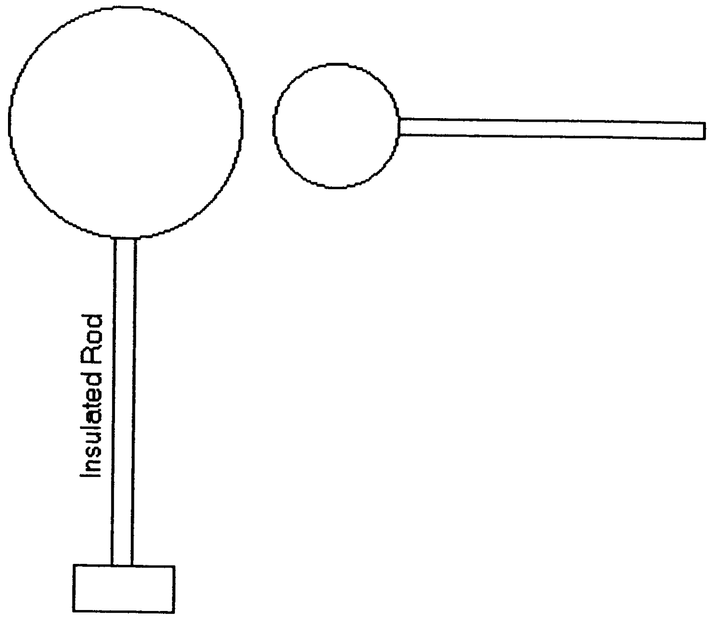

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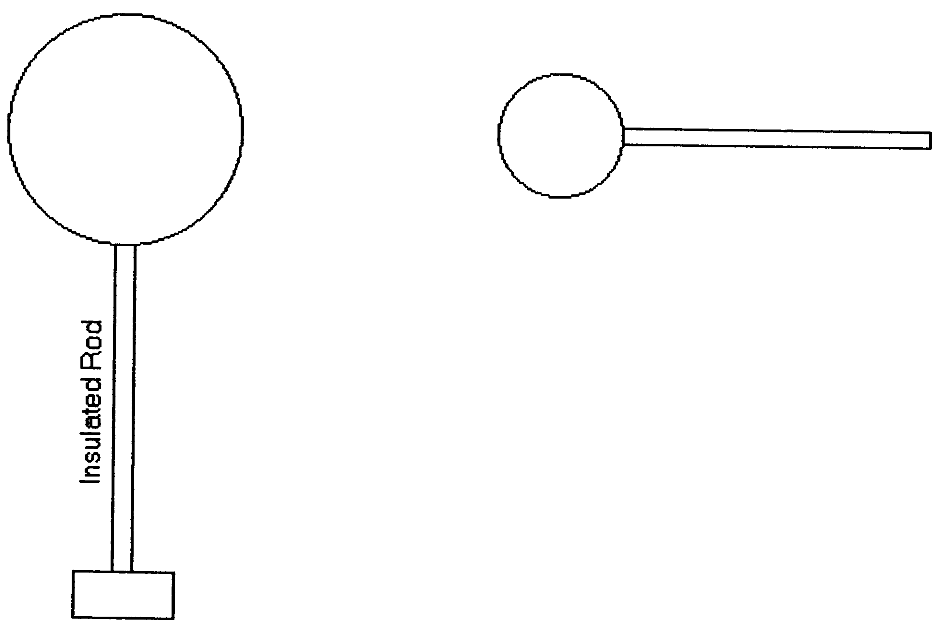


Appendix I: Test 1

Name:____________________

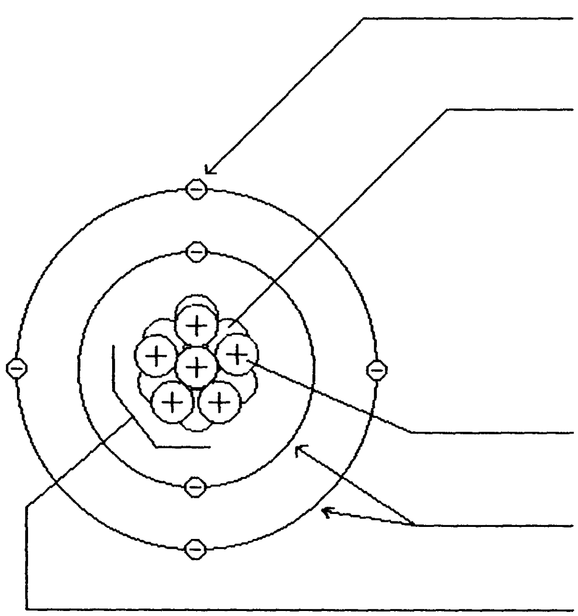
Post Survey
Basic Atomic Theory and Electrostatics

1 (a) What are the three main sub-atomic particles in an atom.

(b) What is the charge of each?

(c) Which one has the least mass? Which two have about the same mass?

2. Label the different parts of the atom shown below.



3. Look at the periodic table and identify which element this atom is.

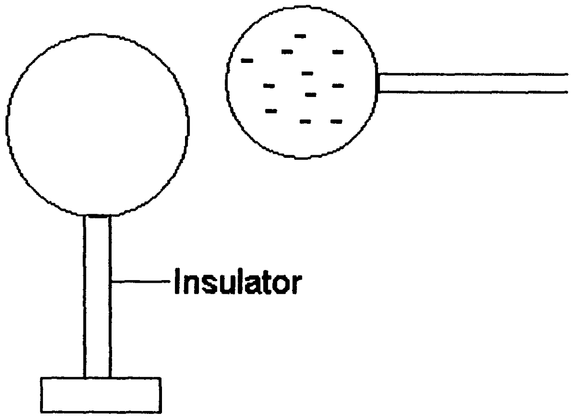
4. What makes elements different from each other?

5. What force holds the electrons to the atom?

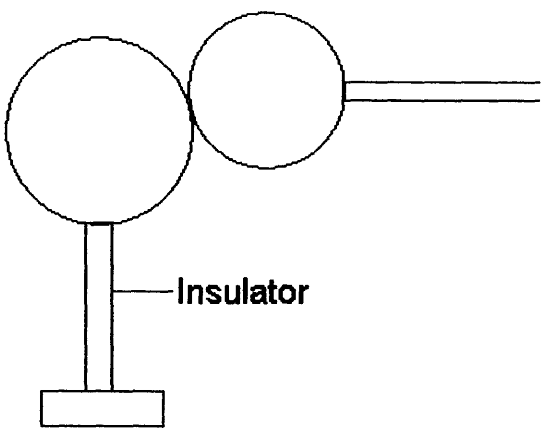
6. If we added or took away an electron, what would we have?

7. What is the difference between a molecule and an atom?

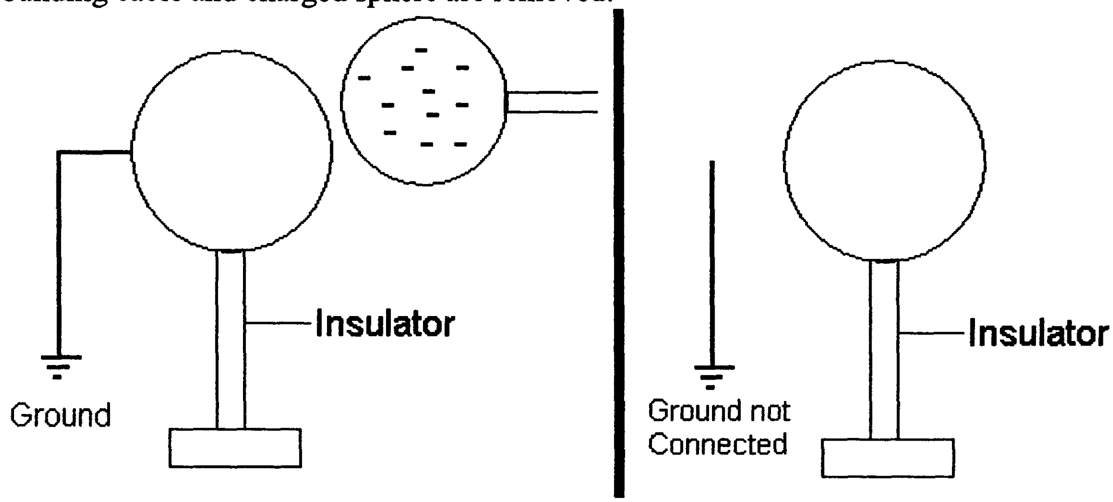
8. In the following scenario, the sphere on the right comes near to the insulated sphere on the left. Draw charge distribution on the sphere on the left. **Bonus**: What type of charging method is this?



9. In this scenario, the spheres shown above come into contact, what will the charges look like on both spheres? **Bonus**: What type of charge transfer is this?



10. In the following scenario, the sphere on the right comes near the grounded sphere on the left. Then the grounding cable is disconnected and the charged sphere is removed. Draw the charge on the insulated sphere and any charge that may be moving on the grounding cable. Then draw the charge that remains on the sphere after both the grounding cable and charged sphere are removed.



Appendix J: Results for First Test

Results of Exam 1

Rank	Student Last Name	Student First name	Student Last Name	Student First name	Score out of 72
1	O'Packi	Kevin	Pancare	Michelle	104
2	Wilkens	Thomas	Mack	Jessica	104
3	Wandrei	Brian	Louchart	Jared	97
4	Gagnon	Corey	Crimer	Tom	97
5	Hickey	Tyler	Johnson	Chris	97
6	Smith	Brandon	Celuaro	Nick	94
7	Molnar	Rick	Trombetta	Chris	81
8	Chase	Emily	Sadler	Hillary	80
9	Mazzaferro	Kristen	Steele	Ryan	76
10	Vincent	Jayson	Bishop	Amy	55

Appendix K: Lesson 6, Electricity

Lesson 6: Electricity

P.O.A.: March 29, 2001

Purpose: To teach the students some of the basics of classical electricity. Focusing mainly on the basics such as current and voltage.

Objectives: To cover the basics of electricity so that they will be able to apply their newly gained knowledge towards a lab that is to be done, in order to explore more deeply the behavior of electricity.

Behavioral Objectives: Since this is the beginning of a new section, there will be some behavioral objectives for this section.

1. For the students to be able to *define* what a voltage is.
2. For the students to be able to *define* what current is.
3. For the students to be able to *distinguish* between current and voltage.

Criteria: Given a problem dealing with electricity the students should be able to

1. Define what current and voltage are, denoting a general understanding of the concepts.
2. The students should be able to describe the differences between voltage and current.

To start the class: The web is an excellent resource to use if you are confused about things. This is just one of the many links I found that explains Voltage, Current and Resistance. http://learn.western.tec.wi.us/circuit/Cffs/cf1/cf1unit2/VCRsep.html

The Water Analogy: Used to help visualize the flow of electricity

Before we start talking about electricity, lets take a look at something we can all visualize and understand pretty easily. Here we have a water pump connected by pipe to a valve and the valve is connected back to the bottom of the pump. This system is then filled with water. First let's assume the pump on all the time at the same speed.

Situation 1

Question: What happens when we leave the valve all the way open?
Answer: The pump is creating a constant pressure forcing the water through the pipe. Since the valve is open all the way your getting the maximum amount of flow.

Situation 2

Question: Now what would happen if we shut the valve about half way?
Answer: The pump is still applying the same amount of pressure but not as much water is getting through. The valve is resisting the flow of water.

Situation 3

Question: Now we shut the valve all the way disconnecting the pipes from each other, what happens?

Answer: The pump still applies a constant pressure but no water moves. The valve is completely resisting the water. For all intents and purposes the pipes are no longer connected.

Now lets make an analogy between that water system and an electrical system. The water pump becomes a battery, the pipe becomes the wire, and the water becomes the free electrons in the wire. The valve can become a switch or a resistor depending on its position

Below we have a battery connected to a wire then a switch and another wire back to the battery. When the switch is closed the electrons flow freely nothing is resisting their flow. This is just like situation 1, with the valve all the way open.

Question: Now lets open the switch what do you think will happen?
Answer: No electrons will flow because the wire is not connected. An open switch is the same as a closed valve.

Finally if we replaced the switch with a resistor it would be analogous to the second situation. The resistor acts like a halfway open valve. A resistor lets some of the electrons through but not all.

So what is electricity? Electricity is the continuous flow of electrons. But what makes these electrons move? The answer is Voltage.

VOLTAGE: The potential electric energy difference per unit charge expressed in volts

Lets take a look back at static electricity. We put some amount of work/energy into scuffing our feet across the carpet. The work/energy is now stored as potential energy, the imbalance of electric charge we've created. This potential energy is known as voltage. When we touch a doorknob or something grounded, we released that potential energy, and electrons flowed between the doorknob and us. There is no potential energy between us and the object and thus no voltage.

So if we have a electron (negative charge) and a proton (positive charge), we know there is an electric force between them pulling them closer together. It takes energy to hold them apart. The amount of energy per unit charge it takes to hold them apart at an amount of distance X is the voltage between them.

Lets look back at the water analogy. What does the pump do? It applies pressure to the water causing it to move. Voltage is analogous to pressure. It's the force applied to the electrons to get them to move.

A very common voltage source is the battery. Batteries convert chemical energy into electrical energy. The battery acts as an electron pump placing electrons at its negative end and extracting them at its positive end. Voltage is not moved, electrons are. Voltage is applied to the electrons, then the electrons move. Remember voltage is the amount of energy available to move electrons.

HOW A BATTERY WORKS: Lets take a car battery for example. Draw simplified sketch ion the board. We have a tub of sulfuric acid on one side a lead plate (Pb) and the other a lead oxide plate (PbO_2). The acid reacts with both metals forming lead sulfate ($PbSO_4$),water and 2 electrons. These electrons come from the lead oxide plate and collect on the side of the lead plate, creating an imbalance of charge, thus a voltage potential. An important thing to keep in mind is that this reaction will only occur if there is some connection between the + and – terminals.

CURRENT: **The flow of electrons due to some applied difference in** voltage.

Lets think back to static electricity for a moment. Lets say we have a wire one end is attached to ground, at the other end we hold a positively charged sphere near it, we know that there is an electric force that attracts positive charges to negative charges. So we know that the sphere will induce a negative charge on the wire. Electrons will move from ground onto the wire, when enough electrons accumulate to balance the positive charge, they stop flowing up the wire. We had a current in the wire for a brief moment when we brought the positive sphere near it. But now we have reached equilibrium. And no more electron flow, we no longer has a current. The end result is that in static electricity there is no continuous movement hence the title static electricity.

Now lets look at this situation. We have a wire and across it we place a voltage difference. To create this potential we place a positively charged sphere at one end and a equally negatively charge sphere at the other. We then touch the spheres to either end at the same time.

Question: What happens? You should know this; you were just tested on it.
Answer: The extra electrons on the negative sphere are attracted to the positive sphere. They flow through the wire and neutralize the charge. There is no longer a voltage difference. But only for a brief moment they flow. The end result is again static; there is no continuous movement.

Now lets try to make a continuous flow of electrons, a constant current through the wire.

Question: Why did the electrons stop moving in the previous example?
What was making them flow?
Answer: The electrons stopped flowing because they there was no longer a voltage difference between the two ends of the wire. In other words there was no longer a negatively charge at one end and a positive at the other.

What if we had a constant voltage difference that would not go away? What if we could maintain a positive charge one end and a negative charge on the other? What would happen is that electrons would constantly flow through the wire and we would then have a constant current. So we now know we need a constant voltage source to generate a current.

Question: Can anyone name a constant voltage source that they know of? Hint I just discussed one with you earlier.
Answer: A battery.

Like discussed earlier a battery has a chemical reaction inside that takes electrons from one end (positive terminal) and places electrons at the other end (negative terminal), but only when a conductive path (such as a wire) connects the two ends. When a wire connects both ends a continuous chemical reaction occurs that creates and constant imbalance of charge between the terminals, in other words creates a constant voltage difference between the two terminals. Thus a battery is a constant voltage source.

Here's a recap of what is going on. Here we have a battery hooked up to a piece wire. The battery produces a constant voltage across the wire. Think of this voltage as an electrical pressure, forcing the electrons to move through the wire from on end to the other. The voltage is the force that moves the electrons though the wire. If you had a tube (wire) full of ping-pong ball (electrons), and pushed (applied voltage) one ping-pong ball (electron) in on one side one ping-pong ball (electron) would fall out on the other.

Lets make sure you know what's going on now.

Question: What is causing these electrons to move through the wire? Yes we know it's the battery, but what is the battery doing?
Answer: The electrons are moving because of the voltage potential across the wire generated by the battery.

Question: What is voltage/electric potential.
Answer: It's the amount of energy per unit charge available to move the electrons, or any charged particle for that matter.

If you had 2 parallel plates with a voltage across it and placed a negatively charged particle in it, it would be pull to the positive side. If you placed a positively charged particle it would be pulled to the negative side.

Question: Why is the flow of electrons continuous?
Answer: The battery is constantly generating a voltage difference across its terminals.

MORE CURRENT STUFF

This needs to be pointed out. **Electrons flow from negative to positive!** The electrons are what are moving. Now way back when in the 1800's when atoms and sub-atomic particles where not understood. It was thought that the positive charges move, this was basically a guess and they were wrong. As we know the positive charge in the atom, is the proton. The proton is contained in the nucleus, and the nucleus does not move. But they did not know this back then. So it was though that positive charges move from positive to negative. This is known as conventional current. Its still the standard widely used today. Now you may ask if it's wrong why are they still using it? Because it works, you will see why this erroneous assumption still works later on. Basically assuming that current flows from positive to negative results in a sign error +/- in you current value. Don't worry about this now. I just want you to be aware because you may open up a text book some where and you may see current shown flowing from positive to negative. The textbook is not wrong it just uses conventional current as opposed to electron flow.

DC Current

In everything we have discussed so far the electrons are moving in one direction all the time. This is known as direct current, or DC electricity. The current move in one direction only because the voltage polarity does not change. The batteries terminals do not change, one side is always positive and the other always negative. If we were constantly flip the batteries connection to the wire, current would flow one way then when the battery flipped it would flow the other way this type of current is known as alternating current or AC electricity. The wall outlets in this classroom are AC. Meaning current flows one direction and then switches and flows the other direction. We will not be focusing on AC.

The Coulomb: We now what current is, it is the flow of electrons. But that's a general definition, lets refine this definition some more in terms of exactly how is measured. First off charge is measured in coulombs, in static we did not really go into depth of the units in which we measure charge it was not as important as learning how it behaved, we just gave it arbitrary units of +4 positive charge or –8 negative charge. An electron has the charge of about $1.6x10^{-19}$ coulombs. So 1 coulomb is 6.28x1018 electrons. That is a lot of electrons.

Chris's rant on putting everything into scale (do not take notes on this)

These numbers seem ridiculously huge. But lets put those numbers in to a better perspective. A 1cm cube of copper contains about $2.4x10^{24}$ electrons and $8.5x10^{22}$ free electrons. Remember free electrons are those separated from the atom. But since they are still contained in the copper the copper remains neutral. So first off $(8.5x10^{22})/(2.4x10^{24})$ is .0354. So out of all the electrons in copper about 3.5% of them are free at room temp.

See sheet of calculations.

So in the end one coulomb of charge is about .00026% of all the electrons in 1 cc of copper. A very very small amount of electrons move. Don't be fooled by these huge numbers!

Define: Current - The flow of charge at one point per unit time.

Current is measured in amperes. One ampere or (amp for short) is 1 coulomb per sec. In terms of electrons, $6.28x10^{18}$ electrons per sec. That sounds pretty fast right? Wrong. Don't let these big numbers deceive you.

Picture this if we had a $6.28x10^{18}$ ping-pong balls and a tube whose diameter was 1 ping-pong ball lets say 4cm wide, the ping-pong balls would have to be moving thousands of time faster than the speed of light to be moving at $6.28x10^{18}$. But now picture this lets say in the diameter of the pipe you could fit all $6.28x10^{18}$ ping-pong balls. The ping-pong balls would only have to move at a speed of 4cm/sec to achieve $6.28x10^{18}$ ping-pong balls/second. Wires are the same are like huge tubes. Millions of electrons can fit in the diameter of a wires. So the electrons do not have to move that fast at all to achieve 1ampere. In fact the speed of electrons in a wire is very slow. For 100V @ 1ampere an average speed value is 8.4cm/hour or .0023cm/sec for .2cm diameter wire. That's slower than flowing molasses syrup.

Appendix L: Electrical Circuits

Lesson 7: Electricity
P.O.A.: March 30, 2001

Purpose: To teach the students some of the basics of classical electricity. Focusing mainly on the basics such as current and voltage. This will be a continuation of the previous day, with a greater focus on attributes that will allow the students to apply their new knowledge towards that lab.

Objectives: To cover the basics of electricity so that they will be able to apply their newly gained knowledge towards a lab that is to be done, in order to explore more deeply the behavior of electricity. This lesson will reinforce the student's knowledge of voltage and current, and will explore areas such as circuit diagrams and the different types of circuits.

Behavioral Objectives: Since this is the beginning of a new section, there will be some behavioral objectives for this section.

4. For the students to be able to *define* what a series circuit is.
5. For the students to be able to *define* what a parallel circuit is.
6. For the students to be able to *apply* the equivalent resistance formulas to circuit diagrams for analysis.
7. For the students to be able to *construct* circuits when given a circuit diagram.

Criteria: Given a problem dealing with electricity the students should be able to

3. Identify what different parts on a schematic representation are.
4. Successfully calculate equivalent resistances of simple arrangements of series circuits.
5. Successfully calculate equivalent resistances of simple arrangements of parallel circuits.
6. Successfully calculate equivalent resistances of simple arrangements of series and parallel circuits.

To start the class Chris will begin with a review of voltage and current.

VOLTAGE: The potential electric energy difference per unit charge expressed in volts.

Gave the example of the charged sphere. Starts out with some stored voltage, when contacted with ground, there would be a flow of electrons for an instant till the system reached equilibrium. When a battery is added instead to a charged sphere, there can be a continuous flow of electrons.

Reviewed battery: Basic how it works, provides a continuous difference in voltage, thus converted chemical energy into electrical energy.

CURRENT: The flow of electrons due to some difference in voltage.

Electrical circuits: An arrangement of electrical elements that allows for there to be a flow of electricity. The most simple would be a battery and a wire loop.

Circuit elements: voltage source, conductor, resistor, light bulb, switch, capacitor, LCD, LED, potentiometer, and diodes

Conductors: wire, foil on circuit boards, ground (earth ground), car chassis

First draw a representation of a flashlight onto the board. Ask the students if they know what it is.

Next draw the wiring schematic for the flashlight on the board and have the students identify the different representations with their physical counterparts.

Following this general procedure, we establish a key of circuit elements for the students to refer to. Included on this key are the battery, the light bulb, the resistor, and the switch. There are many more, but for this elementary introduction this is all that we will concern ourselves with.

Series circuits: An arrangement of circuit elements that allows for there to be only one path of current. Voltage dividing (Draw on board)

Parallel Circuit: An arrangement of circuit elements that allows for multiple paths of current. Current dividing (Draw on board)

Equivalent resistance: The resistive equivalent of an arrangement of resistors in a circuit, i.e. what you would have if you took all of the resistors in a circuit and combined them in to one.

You would do this to simplify calculations, and also to achieve non-standard values of resistance.

Adding resistances in series:

$$R_{eq} = R1 + R2 + R3 + \ldots + R_n$$

Where n = number of resistors

Draw an example on the board and work through an example with them

Adding resistances in parallel:

$$1/R_{eq} = 1/R1 + 1/R2 + 1/R3 + \ldots + 1/R_n$$

Where n = number of resistors

Draw an example on the board and work through an example with them

Appendix M: Lab 1, Discovering Ohm's Law

Lab 1: Exploring electrical circuits

Name______________________________

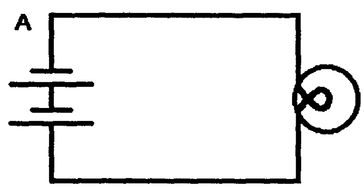
Purpose: The purpose of this lab is to gain some experience with electrical circuits, and to apply equivalent resistances to a circuit in order to derive the relation between voltage, resistance and current known as Ohm's Law.

Objective: There is a simple mathematical relationship between voltage, resistance and current. By measuring the current flowing though various resistors and observing the trends that occur we will try come up with a formula that will relate voltage to resistance and current.

Materials: 2 batteries and holders, 1 knife switch, 5 connectors, 3 pieces of wire, 2-25ohm resistors (red | yellow | black | gold), 4-50ohm (green | brown | black | gold), 1 light bulb holder.

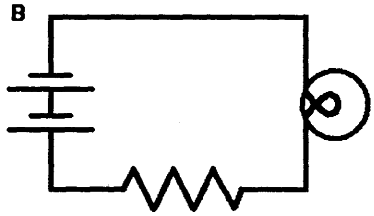
Part 1: For the first part we want to make a simple circuit that has a light bulb in series with the two batteries and the knife switch, this is basically the flashlight that we drew on the board yesterday. See circuit diagram A below. Close the circuit and observe the brightness of the light. Record observations below.

A



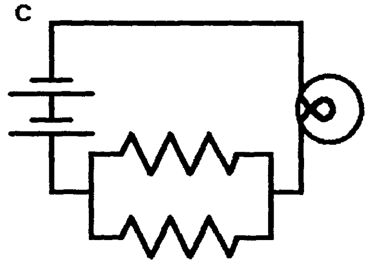
Next add a 25ohm resistor in series with the light bulb as shown in circuit diagram B. Observe the brightness of the bulb.

B



Finally add another 25ohm resistor parallel to the first as shown in circuit diagram C. Observe the differences in brightness between the bulbs in these 3 situations.

C



Things to consider: Why is the light bulb brighter with the two 25ohm resistors, shouldn't it be duller since there are more resistors? Why is this not true?

<u>Observations:</u>

Part 2: Combining Resistors to Achieve a Desired Resistance

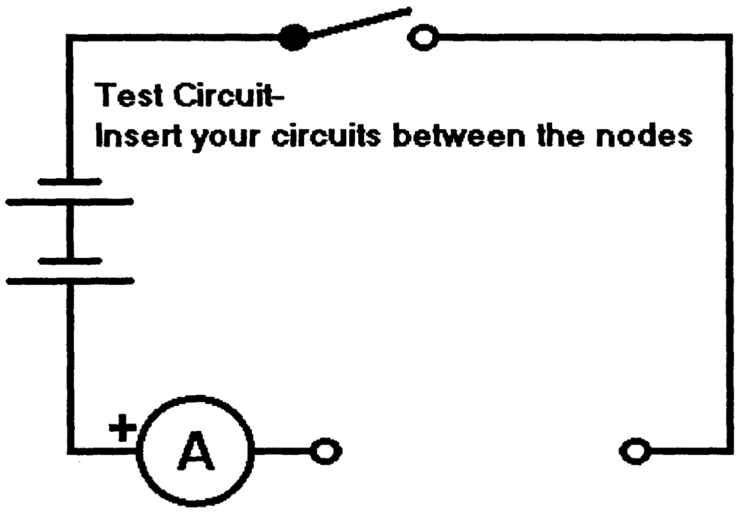
Given 4-50 ohm resistors, using as many or as few as needed created an equivalent resistance that is equal to the one specified in each box and draw a circuit diagram of each circuit that has only the resistors, we will add the batteries later so that we can take some measurements. Have one of us check to make sure that everything is right before you go on to the next part. Draw your circuit between the nodes so that it will be easy to add to the circuit with the batteries that we will be using later.

50-ohm **o** **o**	150-ohm **o** **o**	12.5-ohm **o** **o**
200-ohm **o** **o**	25-ohm **o** **o**	100-ohm **o** **o**

Part 3: Discovering the Relationship Between Voltage, Current and Resistance

For this part of the lab we will take the circuits that you developed above and place them into a circuit that contains a voltage source (the two batteries), a switch and an ammeter. The ammeter is that device that has the needle on it. It is used to measure the current that is flowing through a circuit, or a part of a circuit. In order to work properly an ammeter needs to be connected inline with the circuit where the current is to be measured.

Construct the test circuit, and each of the circuits that you have developed above. For each one close the switch and record the current that is flowing through the resistor. Record these results in the table below. *I is used to denote current



Record the results here. The ammeter that you are using measures in milliamps (mA) so it is necessary to make a conversion from milliamps to amps by multiplying the milliamps value by ten to the negative three in order to get amps, which we will be using later.

V (volts)	R_{eq} (ohms)	I (mA)	I (A) (1A=1mA x 10^-3)
3V			
3V			
3V			
3V			
3V			
3V			

Try to figure out the relationship between current resistance and voltage. Consider what happens to the current when the resistance is doubled.

The relationship between voltage, resistance and current is?
(**hint:** start by writing V = ?)

Finally using the equation you just derived and the ammeter find the resistance of the light bulb.

Appendix N: Test 2, A Cumulative Exam

Name____________________

Exam II

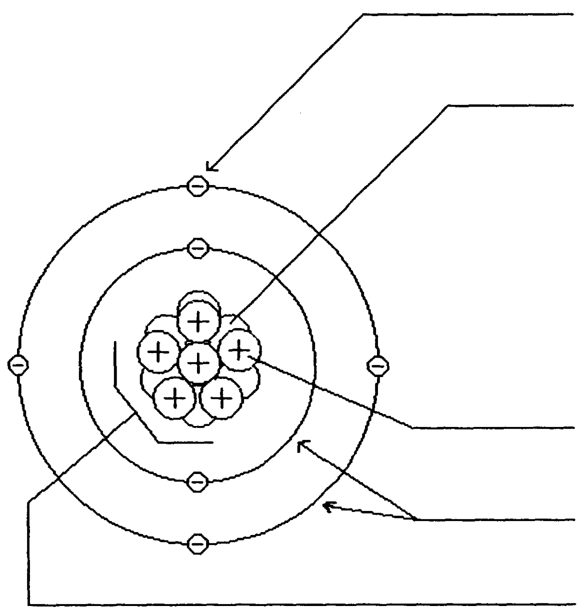
1) Name the three main sub-atomic particles in an atom and write out their charge.

____

____

____

2) Label the different parts of the atom shown below.



a. Nucleus

b. Electron Shell

c. Molecule

d. Proton

e. Neutron

f. Electron

g. Photons

3) What force holds the protons together in a nucleus?

A. Electric Force
B. Strong nuclear force
C. Weak nuclear force
D. Ionic bonding
E. Magic

4) What determines what element an atom is?

A. The color of the atom
B. The number of electrons
C. The number of protons
D. The number of neutrons
E. Both B & D

5) Current is best defined as?

A The Potential electric energy difference between to points
B The flow of voltage through a material due to the electric force
C The flow of electrons through a material due to some applied voltage
D Amperes
E Mickey Mouse

6) Voltage is best defined as?

A The flow of electrons through a material due to some applied voltage
B The Potential electric energy difference between to points
C Static electricity
D Volts
E Donald Duck

7) A light bulb is an example of a?

A Resistor
B Voltage source
C A bright idea
D A circuit element
E Both A & D

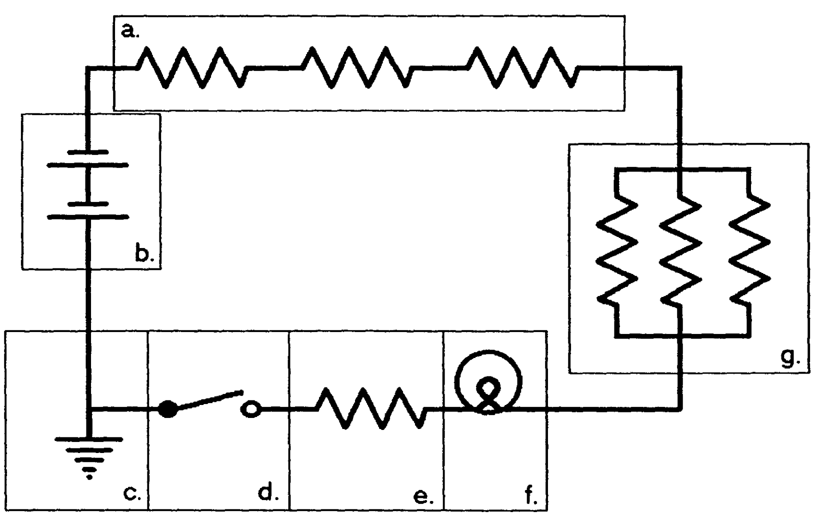
8) A resistor does what?

A Opposes current flow
B Opposes the voltage
C Conducts electrons very well
D Both A & C

9) A battery does what?

A Provides a constant voltage
B Acts as an "electron pump" moving electrons from the + side to the - side
C Transforms chemical energy into electric energy
D All of the above

10) Match the part of the electrical circuit below with it's corresponding name to the right.



Switch ______________________

Battery ______________________

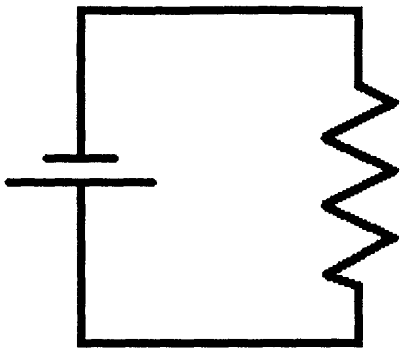
Resistor ______________________

Parallel Circuit ______________________

Series Circuit ______________________

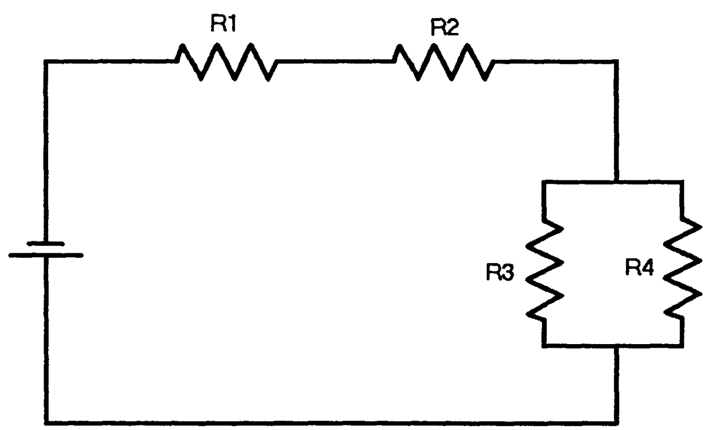
Light bulb ______________________

Ground ______________________



Circuit 1. Use for Problem number 11

11) If you added a resistor in <u>parallel</u> to the resistor in Circuit 1, what would happen?
- A The voltage would increase and the resistance would decrease
- B The current would decrease and the voltage would remain the same
- C The resistance would decrease and the current would decrease
- D The current would remain the same and the resistance would decrease
- E The current would increase and the resistance would decrease
- F Both A & C



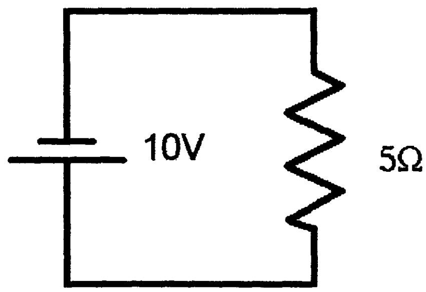
Circuit 2. Use for problems 12 and 13

12) The current in Circuit 2 is?
- A The same through each resistor
- B The each resistor will have a different current value
- C The current will be the same through R1 and R2, R3 and R4 will have different currents
- D The current will be the same through R3 and R4, R1 and R2 will have different currents

13) The voltage in Circuit 2 is?
- A The same everywhere
- B Different at every point
- C Different across R3 & R4, but the same across R1 & R2
- D Different across R1 & R2, but the same across R3 & R4

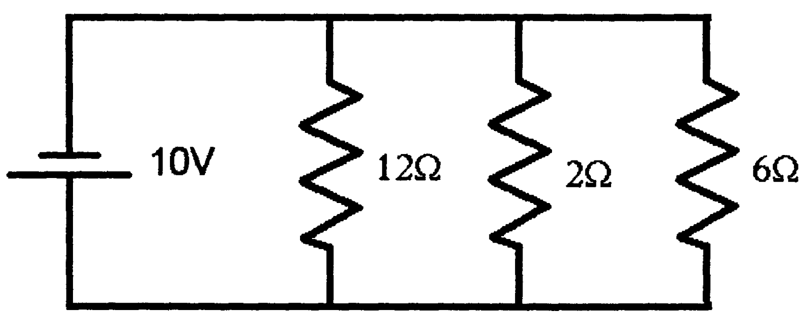
Part 2. <u>Short answer</u>. Please show calculations, **at least: a formula, a formula with numbers plugged into it, and an answer.**

14) Given an electrical circuit, shown below, with a 10-volt battery and a 5-ohm resistor, determine the current that flows through the circuit.



I = ________________

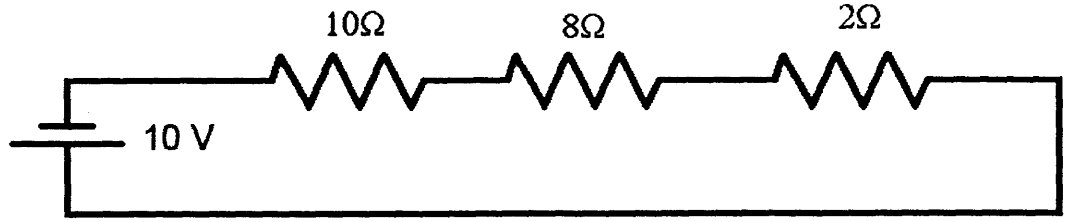
15) Given the electrical circuit below, first find the equivalent resistance, and then find the current that flows through the 2-ohm resistor.



R_{eq} = ______________

I (through 2-ohm resistor) = ______________

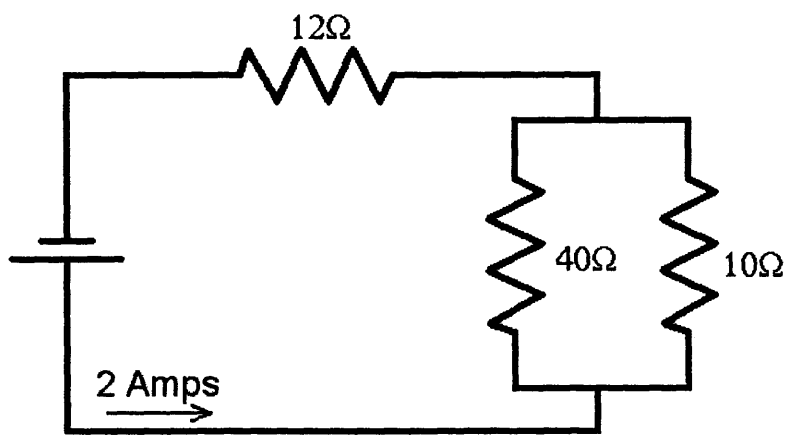
16) Given the following circuit located below, calculate the equivalent resistance, and use that to find the current (I) that flows through the entire circuit.



R_{eq} = _______________

I = _______________

17) Given the following circuit, determine the equivalent resistance of the circuit network, and find voltage of the battery.



R_{eq} = _______________

V = _______________

Appendix O: Results of Test 2

Results for Second Exam

			EXAM II					
Exam II Rank	Student Last Name	Student First name	Score out of 101	Adjusted Score out of 86	Bonus Points 11	12	13	Final Score out of 86
1	O'Packi	Kevin	91	100	0	0	5	105
2	Smith	Brandon	89	98	0	5	0	103
3	Wilkens	Thomas	87	95	5	0	0	100
4	Wandrei	Brian	87	95	5	0	0	100
5	Louchart	Jared	86	94	0	0	5	99
6	Chase	Emily	84	97	0	0	0	97
7	Gagnon	Corey	82	95	0	0	0	95
8	Molnar	Rick	76	88	0	0	0	88
9	Hickey	Tyler	77	83	0	0	5	88
10	Trombetta	Chris	72	85	0	0	0	85
11	Celuaro	Nick	70	81	0	0	0	81
12	Mazzaferro	Kristen	69	80	0	0	0	80
13	Steele	Ryan	62	72	0	0	0	72
14	Crimer	Tom	59	62	0	0	5	67
15	Johnson	Chris	49	56	0	0	0	56
16	Sadler	Hillary	47	49	5	0	0	54
17	Mack	Jessica	45	52	0	0	0	52
18	Pancare	Michelle	44	51	0	0	0	51
19	Vincent	Jayson	43	50	0	0	0	50
20	Bishop	Amy	44	45	0	5	0	50
21	Hamalainen	Domielle	37	37	5	0	5	47

Exam II Average
77.14

Exam 2 Breakdown of Results Question by Question

Problem	Answer	Correct	Positive	Neutral	Negative
1	Proton	90.48%	19		
	Neutron	90.48%		19	
	Electron	90.48%			19

Problem	Answer	Correct	A	B	C	D	E	F	G
2	Electron	95.24%					1	20	
	Neutron	90.48%				1	19	1	
	Proton	95.24%				20	1		
	Shells	100.00%		21					
	Nucleus	100.00%	21						

Problem	Correct	A	B	C	D	E
3	47.62%	8	10		3	
4	52.38%		2	11		8
5	66.67%		7	14		
6	85.71%		18	1	2	
7	61.90%	3	3		2	13
8	66.67%	14	2	2	3	
9	76.19%	2	2	1	16	

Problem	Answer	Correct	A	B	C	D	E	F	G
10	Switch	100.00%				21			
	Battery	95.24%		20					1
	Resistor	100.00%					21		
	Parallel	95.24%	1						20
	Series	100.00%	21						
	Light Bulb	100.00%						21	
	Ground	100.00%			21				

Problem	Correct	A	B	C	D	E	F
11	19.05%	4	8	3	1	4	1
12	9.52%	4	6	2	9		
13	19.05%	9	1	7	4		

Problem	Correct	I
14	90.48%	19

Problem	Correct	Req	Correct	I
15	61.90%	13	57.14%	12
Problem	**Correct**	**Req**	**Correct**	**I**
16	80.95%	17	66.67%	14
Problem	**Correct**	**Req**	**Correct**	**V**
17	47.62%	10	52.38%	11

Appendix P: Results of Mrs. Petit's Survey

WPI Evaluation
Grade 8 Mrs. Petit's Physical Science Class

Rate the following areas of the class. One (1) being poor through five (5) being excellent.

	1 = poor	2 = fair	3 = good	4 = v. good	5=excellent
1. Lecture (notes)	1	2	3	4	5
2. Handouts	1	2	3	4	5
3. Lab	1	2	3	4	5
4. Visuals	1	2	3	4	5
5. Overall class	1	2	3	4	5

Comments/ Suggestions:

Write a brief paragraph evaluating Josh and Chris' electricity class, include and positive comments you may have, as well as constructive criticism.

	Question Number				
Student #	1	2	3	4	5
1	2	3	4	4	3
2	3	2	3	4	3
3	3	4	4	4	4
4	4	4	5	5	4
5	5	4	4	5	4
6	4	4	5	3	4
7	4	3	4	3	5
8	4	3	4	3	4
9	4	5	4	4	5
10	4	5	4	4	4
11	4	4	4	4	4
12	2	4	5	2	3
13	3	4	5	4	4
14	3	3	5	4	5
15	5	4	4	4	4
16	4	3	4	4	4
17	1	3	5	3	2
18	2	3	4	3	3
19	3	3	4	5	4
Total	65	68	81	72	73
Average	3.42	3.58	4.26	3.79	3.84

Areas of Class		**Average Rating**
1	Lecture (notes)	3.00
2	Handouts	3.95
3	Lab	3.26
4	Visuals	4.00
5	Overall Class	4.10

Appendix Q: Results of Our Student Survey

Post Survey

1-Strongly Agree . . . 2 –Disagree . . . 3 –Neutral . . . 4 –Agree . . . 5 -Strongly Agree

		1	2	3	4	5
1	The material was difficult.					
2	The pace of the learning was fast.					
3	Having class only twice a week made the learning hard.					
4	I learned a lot about electricity.					
5	Having two people teach helped.					
6	The lab helped me to better understand electricity.					
7	I could now explain to a fellow classmate what electricity is.					
8	The visual demonstrations helped me to learn.					
9	The demonstrations were fun.					
10	Constructing the circuits in lab was fun.					
11	I would like to continue lessons with Chris and Josh.					
12	This class made us more interested in electronics.					
13	I realized the material we are learning is usually taught junior year in High School.					

What would you suggest to improve the quality of the lessons?

What did you particularly like about out lessons?

What did you dislike about our lessons?

Results of Our Survey

	Question Number												
Student #	1	2	3	4	5	6	7	8	9	10	11	12	13
1	4	4	4.5	5	4	4	3	4	4	4	3	3	5
2	3	3	2	4	4	5	3	5	5	4	5	4	5
3	3	3	2	4	4	4	3	4	4	4	4	4	3
4	4	4	4	4	5	5	3	4	5	5	5	4	4
5	2		4	3	3	4	3	4	4	4	3	3	4
6	4	5	4		4	2	4	5	5		3	4	5
7	4	3	3	4	4	4	4	4	4	4	5	4	4
8	2	5	3	5	5	5	4	5	5	5	5	4	4
9	3	4	2	5	5	4	3	5	5	4	5	4	4
10	3	5	4	5	2	4	3	5	4	4	4	3	5
11	2	3	3	4	4	4	4	4	4	4	4	4	4
12	2	4	2	3	4	4	4	4	4	4	4	3	4
13	3	3	3	4	5	4	5	3	4	4	4	4	5
14	3	4	4	4	5	4	3	3	4	4	4	5	5
15	3	5	3	4	3	3	4	3	5	4	4	3	5
16	4	5	3	4	4	5	3	4	5	5	3	4	3
17	1	3	5	5	5	5	1	5	5	5	5	5	5
18	4	4	4	3	5	5	4	5	5	5	4	3	5
19	3	4	3	4	4	4	5	4	4	3	4	3	2
20	3	4	3	4	3	2	4	4	5	5	3	4	3
21	2	4	3	2	4	4	3	4	5	4	3	3	
Total	63	79	68.5	80	86	85	73	88	95	85	84	78	84
Average	3	3.95	3.262	4	4.095	4.048	3.476	4.19	4.524	4.25	4	3.714	4.2

	Question	Average Rank
1	The material was difficult.	3.00
2	The pace of the learning was fast.	3.95
3	Having class only twice a week made the learning hard.	3.26
4	I learned a lot about electricity.	4.00
5	Having two people teach helped.	4.10
6	The lab helped me to better understand electricity.	4.05
7	I could now explain to a fellow classmate what electricity is.	3.48
8	The visual demonstrations helped me to learn.	4.19
9	The demonstrations were fun.	4.52
10	Constructing the circuits in lab was fun.	4.25
11	I would like to continue lessons with Chris and Josh.	4.00
12	This class made us more interested in electronics.	3.71
13	I realized the material we are learning is usually taught junior year in HS.	4.20

Typical Comments From Short Answer Questions

What would you do to improve the quality of the lessons?
Explain the material more thoroughly. (3)
Slowing down a bit (16)
Writing more on the board.
Work through a few of the steps. (2)
Break things down more. (3)
Use more demonstrations to put things into perspective.
Making the class more eighth-grade friendly.
Keep on topic. (2)
Cover less material in a class period.
To have longer and more classes. (4)
Try to think from an eighth-graders point of view. (2)

What did you particularly like about the class?
The demonstrations using the Van De Graaff generator. (6)
I liked the doughnuts and how non-pressured the class was.
I really liked the labs. (9)
I liked the demonstrations. (8)
When we had Mrs. Snow (vise principal) on the Van De Graaff.
It was material that we wouldn't normally learn for a few years.
I liked the section on electricity.
Worksheets.

What did you particularly dislike about our lessons?
I didn't particularly dislike anything about the lessons. (7)
How fast the class progressed. (9)
Could have learned more if they went slower
Not enough time to continue with the lessons.
Straggling off topic.
I couldn't understand some of the material. (2)

Appendix R: Review from Project Liaison

Worcester Polytechnic Institute Interactive Qualifying Project
FINAL EVALUATION

Site: Chocksett Middle School
Sterling, Massachusetts

Grade 8 -- Physical Science Class

Sponsor: Mary-Beth Petit
Grade 8 Science Teacher

Students: Joshua Engstrom and Christopher Knight

Joshua and Chris implemented a teaching unit designed for eighth grade students on electricity. The topic for the unit was decided upon after several meeting with Joshua and Chris and a Student Interest Survey created by them. Joshua and Chris spent several months preparing before coming into the classroom to teach. Through email communication and meetings here at the school, Joshua and Chris developed a program to meet the needs of the 8^{th} grade students here at Chocksett Middle School.

I assigned Joshua and Chris one class of approximately 21 students to work with over a four week period. Joshua and Chris taught these students twice a week, approximately 50 minutes each class period. Their lessons included lecture/notes in class, hands-on demonstrations, and a 2 day lab activity. To supplement their lessons Joshua and Chris provided students with handouts, visual aides, test/quiz evaluations and homework assignments. Students kept a separate "WPI class" journal/notebook to keep class information in.

Joshua and Chris had a great rapport with the students. They were very understanding of their needs and were there to help them along the way. They came to class prepared and ready to teach. It was clear to myself and the students that they had an extensive background in this field and the material presented challenged the students!

After each lesson I emailed Joshua and Chris an informal evaluation of the daily lesson that included things that the students liked, as well as any helpful hints or comments for the next lesson. Joshua and Chris were always open to any suggestions or comments that I had. As part of my observation I commented on the overall pace of the classes. Chris and Joshua did work on this aspect. As time proceeded, Chris and Joshua also learned to "break-down" information into simple terms or steps that the 8^{th} grade students could grasp better. These two areas were much improved as the lessons progressed.

At the end of the unit students were given an evaluation form to fill out on Chris and Joshua's lessons. It was clear from the results that the students enjoyed having Chris and Joshua as a part of our class. Students commented on how fun the class was, but also on how much they had learned in the short period of time they had worked with them.

Overall, Chris and Joshua did a wonderful job of implementing a Physical Science unit on Electricity. They handled themselves in a professional manner in the classroom and were very open and willing to working with the students. They represented themselves and the Worcester Polytechnic Institute community very well. Congratulations on a job well done Chris and Joshua!

Mary-Beth Petit
Grade 8 Science Teacher
Chocksett Middle School