This is to certify that the

thesis entitled

Consumer Electronics

presented by

Matthew R. Tuckey

has been accepted towards fulfillment
of the requirements for

Masters Degree degree in Physical Science-
Interdepartmental

Major professor

Date 14 Aug 02

CONSUMER ELECTRONICS:

A HIGH SCHOOL UNIT ON SOLID STATE PHYSICS

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Science and Mathematics Education

2002

ABSTRACT

CONSUMER ELECTRONICS: A HIGH SCHOOL UNIT ON SOLID STATE PHYSICS

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The Consumer Electronics unit developed during this study is a series of labs and lessons designed as an extension of a regular introductory Physics unit on electricity. It is intended to achieve four broad objectives: 1.) To help students maintain a childlike enthusiasm for science. 2.) To provide students practical experience using and extending theories learned in previous lessons. 3.) To develop the idea that real-life situations often require a deeper understanding of physical interactions. 4.) To help students gain the determination and skills required to handle complex problems.

The centerpiece and inspiration for this unit is the construction of a working oven from a tissue box lined with aluminum foil. Developing an understanding of the science principles involved as well as the actual building of the oven comprise the first three weeks. The second half of the unit is an exploration of the physics behind the electrical devices that define our modern world. Based on personal observation and testing of core concepts, I found the teaching of this unit to be successful both in terms of student enthusiasm and involvement.

ACKNOWLEDGMENTS

Many thanks to Dr. Heidemann for helping develop a masters program that is not just a diploma mill, but one that builds better teachers, and for her never-ending supply of patience; to the professors and scholars who work in the Physics lab and machine shop for their generous help; to my daughter Elena and my son Andrew for putting everything into perspective; and most of all to Michelle, my helpmate and best friend.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

I. On the benefits of daydreaming...

The plan to teach a unit on Consumer Electronics began as several incomplete ideas for topics that I wanted to add to my Physics curriculum. The class was in the midst of studying a unit on heat and I had been thinking about how to connect the concept of the units Joules and Watts in terms of electricity to Joules and Watts in terms of specific heats to demonstrate that units are universal. Initially, I was thinking about a lab involving the heating of water with the small heating wands that are used to warm mugs of water for tea. Thinking about heating coils, I decided that it would be better to have the students make their own heating coil with nichrome wire. After having finished a unit on electricity and magnetism this would allow them to gain added experience with the concepts of resistance and joule heating. With the realization that students, exposed electrical wires, and water are not necessarily the best mix, I considered having them use their heating coil to power a small homemade oven instead. This brought about visions of the Easybake oven my sister had when I was younger. Sitting on my desk in front of me during this entire train of thought (daydreaming while my Physics students took a test) was a small Kleenex box. Since the dimensions of the box seemed to work for what I was planning, I used the shape to sketch a design for a small cardboard oven lined with Aluminum foil. At this point the name "Sneezybake Oven" popped into my head and I couldn't help laughing out loud. Even though I was tempted to try building an oven right away, as always with teaching, I had a hundred other jobs with higher priority, so the picture I had drawn was put away and I didn't consider the idea again until the following spring when it was necessary to decide on a thematic unit to develop for thesis research.

By then I had chosen to pursue the possibility/feasibility of having students build these ovens (even though I was unsure of whether the ovens would even work) as part of a larger unit dealing with the "nuts and bolts" physics of electronic devices.

II. For all intents and purposes...

My intent for developing a unit on Consumer Electronics was to help my students gain an appreciation for the practical application of Physics. This would be accomplished by presenting some of the theories of Solid State Physics as they apply to appliances the students use every day, and also by engaging students in lab work building some of these devices. I was seeking to answer a question that, as a teacher, I hear quite often in one form or another: "When are we ever going to use this?". My usual reaction is to want to shout "Right now! You are using it right now, every day and you're not taking the time to think about it!" Other than Introductory Cooking, Physics is probably the most practical science one could take. Therefore, lecture/discussions are filled with as many concrete examples as possible. Still, I felt there was a large gap between the theoretical laboratory work we were doing in conjunction with our electricity unit, and the kind of experimentation that captures student interest. This required labs that give the students a chance to "play" with electricity in the sense that they would feel like real scientists or engineers, and provide work on projects that would give them a feeling of accomplishment. If there isn't a certain degree of fun or imagination built into a science curriculum, you run the risk of losing student interest, and if that happens, student learning becomes difficult. Therefore, it was my goal to develop a unit with activities that would serve two purposes: 1) To demonstrate how principles of Physics are used in common electrical devices, and 2) to be sufficiently engaging that students would invest their minds at a deeper level.

III. Demographics:

The approximately 450 students at BAHS come from families that are a fairly even mix of median-income white households to lower-income white households. Although the area is quite rural (Huron County is the largest producer of agricultural commodities in the state.), Bad Axe is the county seat and therefore many of the students come from white-collar families as well as farms. The normal Physics class load is 25-35 students split between 1-2 classes representing about ¼ of the Senior class. Only a rare few Physics students are underclassmen. This year's class, on which this study is based, was extremely small due to a scheduling conflict with a Calculus class. Of the 15 students that finished the year, there was an almost even mix of boys and girls. At the time this study was undertaken, students only were required to complete two credits of science. The normal progression is General Science in the freshman year followed by Life Science or Biology, after which students can choose from Chemistry, Advanced Biology, or Physics in their junior year. School days consist of six 65-minute periods leaving only a total of 24 credit hours possible. When one considers that 18 of those credit hours are requirements, the number of electives that can be taken is limited. This results in a class of students that really want to take Physics, which has been both a blessing and a curse. I do appreciate that the average student is more focused, but I wish that more students would take advantage of the class.

IV. Timeline:

The first semester of Physics at BAHS is a study of motion and forces and is generally completed by the middle part of December. This is convenient timing for the start of the next unit on Electricity and Magnetism because the dry winter air is favorable to static electricity experiments. Students are introduced to basic concepts about how electrons interact and move within electrical devices. They participate in discussions about the laws of Charles Coulomb, Georg Ohm, and Michael Faraday. Students perform labs that address wiring and electrochemical cells, they build small motors and speakers, and by the end of the unit should have a fairly good grasp of voltage, resistance, and power. The Consumer Electronics unit that is the focus of this study acts as a transition between electricity and a unit that deals with the transfer of heat energy.

V. Discussion of methodology used:

As science teachers, we can find ourselves playing mediator between two opposing forces. On one side we have the students (and sometimes parents and coaches) who are pushing for easier assignments and less homework, while on the opposite side is the administration and our own commitment as professionals pushing to uphold higher standards. There are valid reasons behind both viewpoints. It seems that the young people of today are burdened by too many commitments and responsibilities and there is no doubt that they are stressed for time. However, this does not diminish the need for students to push themselves and stretch their minds. One could even argue that this is the very reason for the existence of schools. As I often find myself telling students, "If this [school, science, whatever…] were easy, there'd be no point in being here."

On the other hand, we teachers often feel we have to pander to the desires of students as a way of bargaining for increased work demands. In some respects this is true, for "Understanding science depends upon curiosity and creativity" (Bioquest, 2002). As stated earlier, we walk a fine line between maintaining student interest and keeping to a schedule. Therefore, it is necessary to use every means at our disposal to succeed in both arenas. This is also why no one educational philosophy should be used by teachers exclusively. As stated in *Classroom Instruction that Works* (Marzano, R., 2001), "No instructional strategy works equally well in all situations." and that, "Teachers should rely on their knowledge of their students, subject matter, and their situation to identify the most appropriate instructional strategies." Some of the most effective strategies listed in this book included; Lecture/Note-taking, Student-centered instructions, Teaching of critical thinking skills, and Hands-on laboratory activities. For this reason (and because it is such a broad framework) the teaching method employed in this unit could best be described as a constructivist approach.

VI. The overlying theory:

The Constructivist Learning Model is "a view of learning that sees learners as active participants who construct their understandings of the world around them." (Brown, J., 2001) They do this by comparing and contrasting new experiences with past knowledge. Since understanding is based on the learners personal past experience, it is of primary importance that the teaching "connect the problem with the context of the student's world." (Savoie, J.M., 1999) To put it another way, if you can relate the topic of a lesson to something that holds the personal interest of a child, that interest will, to some extent, transfer over to the topic. Also it will be easier for the child to accept the validity of the lesson when the phenomenon is something they see in use every day (Minstrell, J., 1989). One of my typical approaches is to center in on one student, and through a roundabout series of questions, draw an example from their personal experience. I then ask how it relates to the topic of our lesson. Sometimes, though, the student might fail to see the connection. In cases such as these the "relevance [of a topic] can emerge through teacher mediation." (Brooks, J., 1993) This is a chance for the teacher to discuss long-range effects, personal responsibilities, or put things into an historical perspective. In addressing relevance, I have tried to choose topics for this unit, and other units as well, that are at the center of an adolescent's world, mainly food.

An important part of Constructivist theory, or any successful teaching philosophy, is that curriculum needs to be highly organized. Even though within the model it is "student thinking, experiences, and interests [that] drive lessons" (Yager, R., 1991), timing and execution should be closely controlled by the teacher. Timing is a crucial part of student learning. "It takes several exposures to material to chew on it long enough to understand it." (Silverman, M., 1996)

As a descendent of Piaget's Cognitive theory, the central theme of Constructivist theory is that knowledge is pieced together from personal experience. Thus it would make sense that the more profound or personal the experience is, the greater impact it will have within the learning process. This reinforces the notion that "students should do science, not just hear or read about it." (Bioquest, 2002) Key to this or any unit are lab experiences that allow students to get their hands dirty in the work of science. Well-designed labs should mimic everyday life as much as possible since students tend to learn better with concrete rather than abstract examples. In my situation it was my excitement over an idea that caused me to consider developing this unit in the first place. There is a moment when you understand how something works that is quite satisfying. In the preface of his book *How Stuff Works* (2001), Marshall Brain writes: "Learning about all the different technologies in our world changes your relationship with them…It is empowering to master their secrets." It has been my hope that as I continue to teach this unit, it will not only have an effect on how well students learn the science involved, but that they might develop an appreciation for it as well.

A fourth element to constructivism is that the teacher should encourage students to discover concepts on their own since, "The constructivist process is shaped by the student, with the instructor acting as the thinking coach." (Greenwald, N., 2000) For the most part, I have been employing many of the elements of constructivism as long as I have been teaching, including encouraging students to discover things on their own. However, within this unit, I am encouraging this self-discovery to a greater extent than ever before. The central theme of my Consumer Electronics unit is the Sneezy-Bake Oven lab, and at the beginning of the unit I start a discussion with the open-ended proposal that we build our own ovens from scratch and then use them in a cookie bake-off. My management of that discussion requires a Problem Solving approach.

VII. Open-ended learning methods:

Two years ago a former Physics student told me that she would always remember me telling her class, "We [the teachers] are not here to show you how to make peanut-butter and jelly sandwiches." Although I only vaguely remember making the statement, the sentiment is something I believe in. If we expect to turn out the "critical thinkers" that we refer to in our school's mission statement, then we need to teach students to "learn to learn" (Duch, B., 1995). This is the focus of Problem-Based Learning, that students need to encounter and tackle real world problems that "do not have answers at the back of the book" (Bioquest, 2002). The goal is to turn students into problem solvers.

Problem-Based Learning had its origin in the teaching of interns at McMaster University Medical School and is a concept that hits at the heart of the scientific method. A problem is observed and identified and then students are asked to come up with possible solutions. The operative word here is "possible" since the proposed problems are not meant to have one definite solution. (Stephen, W.J., 1993)

In our case the problem to be solved was how to build an oven out of a cardboard box. Several open-ended questions then arose from this starting point. The value of an open-ended question is that it forces the student to imagine numerous possible situations. For example: If we are making an oven out of a box, how big will it be? How hot will it get? How can we keep the box from burning? It also forces the student to use higher-level thinking skills and develop a better understanding of the core concepts. In building an oven, you have to really understand the physics behind Joule heating in order to make a heating element that is going to operate at a specific number of Watts. This is the kind of analysis that is necessary if students are going to "effectively keep information." (Marzano, R., 2001) This is also the kind of analysis that is necessary to root out and replace prior misconceptions. When higher level thinking is not required, what students learn in class is not applied in the real world. If they are presented with a problem out of context, they "revert to earlier conceptions." (Dykstra, D., 1992)

One problem with using the Problem Solving method is that it is extremely time consuming compared to a more traditional lecture/discussion mode of instruction. In *Dan Tries Problem-Based Learning: A Case Study*, (White, H.B., 1996) a fictitious college professor debates whether this use of time is worth it. Luckily, I am not tied to satisfying the demands of MEAP testing for my Physics classes, so time-wise there is more leeway in the curriculum. I do, however, still run into the problem of sacrificing quality for quantity. There is so much content to be covered within a year that we don't give students enough time to understand the concepts (Brooks, J., 1993). These "strict timelines do not agree with what researchers know about learning for understanding." (Duckworth, E., 1986)

With this problem in mind, I spent five weeks during my research summer developing labs and lectures (each building on concepts learned in the last) that would force students to examine, on a small scale, the behavior of electrons within materials, and relate that behavior to the large scale properties observed in common electrical devices. The "Playing Around With Resistance" lab (Appendix IV-B) is meant to show the connection between electron interactions and the electrical resistance within wires. The "Solid-State Physics" lecture and demonstrations (Appendix XII-A) are designed to explain how atoms with different numbers of valence electrons are alloyed to produce semiconductor devices such as solar cells, diodes, and transistors. By extending the basic electricity unit I had been teaching, students better understand core concepts because they are repeatedly putting them to use.

Project-Based Learning is another open-ended method that is similar to Problem-Based except that the end result is not a solution but rather a product. In preparing this unit, my initial plan was to have students get involved with an in-depth project building a homemade version or small model of an electrical appliance or toy. Individual lab groups could choose from a list of ideas such as metal detectors, microphone/amplifiers, crystal radios, and cotton candy machines, or they could come up with their own. The thought was that students would use the same problem-solving methods to complete the project, but this would be done more independently in small groups rather than as a class. Regrettably, this did not occur during this study because I didn't allow enough time before the end of the marking period.

Unfortunately, as teachers, the clock will always be our worst enemy, especially when engaging in problem or project-based instruction. We start our school years and our school days with high hopes and big plans, but in the end if those hopes and plans are not realized, it's usually not because of a lack of effort, or support, or even lack of funds, it is usually because we simply ran out of time. It is important then, that we keep in mind that our job as educators is not to cover a certain amount of material, but to "enhance and expand the student's natural curiosity" because, "if we teach thinking skills, content emerges as a desirable and necessary side effect." (Lindsey, C., 1988) After all, what's important is not that a student learns how to diagram a sentence or factor a polynomial, but that they develop the skills and discipline that it takes to succeed in life.

IMPLEMENTATION OF THE UNIT

I. To begin with:

Given the significant amount of time spent working on the sequence of lectures and lab work in this unit, it makes sense that it be presented as it was intended; as a day-by-day schedule of how activities were planned. The course is meant to follow a weekly rhythm so that any particular teaching methods such as lecture/discussions or lab work, do not occur more than twice in a row and not more than three times in one week. I have also tried to keep Fridays fairly hands-on and free from any heavy discussions since, as my limited experience has taught, this is a waste of time. In the first few weeks, the focus is on electron behavior within metals, leading into the Sneezy-Bake oven lab and our cookie contest. The second portion deals with electron behavior in semi-metals and the development of solid-state technology. The schedule is, of course, meant to be flexible and was changed dramatically at least twice before the unit even began.

II. Summary Schedule of Events:

Day 1	Completion of Consumer Electronics pretest
Day 2	Introduction of Sneezy-Bake Oven Project ("Nothin' Says Lovin' Like Somethin' From the Oven")
Days 3-4	Discovery lab on resistance in wires (Playing around with Resistance)
Days 5-6	Lecture/discussion on resistance (Viva La Resistance!) Building of heating coils and Consumer Electronics worksheet
Days 7-8	Lecture/discussion on the principles of thermocouples and demonstrations of Seebeck and Peltier effects (If You Can't Stand the Heat) Quiz on Resistance (Fight the Power)
Days 9-11	Thermocouple lab (Physics Even a Biology Major Could Love)

Days 12-13	Construction of ovens from tissue boxes (The care and use of your Sneezy-Bake Oven)
Day 14	Vocabulary quiz (Terminknowlogy) Building of cookie sheets and testing of ovens
Day 15	Preparation of cookie dough
Day 16	The Sneezy-Bake Oven Cookie Contest
Day 17	Lecture/discussion on the development of counting machines (Word Processing 1.0)
Day 18	Lecture/discussion on the development of semiconductor devices (Solid-State Physics)
Day 19	Photoelectric effect lab (Solar-Power)
Day 20	Finish lecture/discussion of semiconductor devices
Day 21	Begin individual group building projects (Necessity is the Mother of Invention")
Day 22	Lecture/discussion on the history of computers (Generation 01011000)
Day 23	Lecture/discussion on the inner workings of computers (The Ants Go Marching One By Zero) Byte-Size Problems worksheet
Day 24	Vocabulary Quiz (I'm Just an Analog Kind of Guy in a Digital World) Review sheet (Ready or Not...)
Day 25	Showing of film, "Transistorized"
Day 26	Consumer Electronics test and completion of exit survey (Put Your Two Cents In)

-Individual group building projects to be completed throughout the remainder third marking period

-In-class workdays scheduled as needed

III. Getting the ball rolling:

On the first day after taking their final test of a basic electronics unit, my students were asked to take a Pretest (Appendix II) over the material we would cover in the Consumer Electronics unit. They were asked to make an honest effort at each problem so that I could establish how much prior knowledge of the subject they possessed, and so that I could make a comparison of their results on the same test at the end of the unit to determine how effectively particular concepts were taught. The test included several lower level questions based on terminology and basic information presented during the unit, True/False questions which are notoriously tricky, (but ones that I like because they force the students to think) and two short answer questions (Figure I) that test understanding of how electrical systems work. The last question consisted of a long essay in which students were asked to draw a diagram and use it to explain how a thermocouple works. This was meant to test understanding and how well the students could organize a thoughtful answer. The rest of that day was spent reviewing the results of their test from the previous unit.

IV. Therein Lies the Problem:

The first lesson started with a handout (Appendix III-A) meant to introduce the centerpiece of the unit: The Sneezy-Bake Oven Lab. Using a Problem-Based approach, students were given the challenge to turn a Kleenex box into a working oven, and then asked for input as to how it should be done. Instructor questions were meant only to keep the dialogue moving and students were left free to discuss whatever methods they could come up with. As students came up with ideas, they were written on the board and we evaluated them one at a time. One of the reasons for this approach is that I wanted the students to encounter some of the same problems I had when designing and building the prototype Sneezy-Bake Oven.

We then launched into a lecture/discussion using questions from my lecture notes (Appendix III-B). This was used both as a review of equations from their previous unit as well as a way to guide us through the calculations needed to make a heating coil for our ovens. Assuming that we would want a power output of 70 Watts (this would produced a rate of heating similar to what was provided by the light bulb in early models of the Easybake Oven), we used Ohm's Law and the equation for Joule heating to solve for what the resistance in the wire should be. Once this was determined, the next question was, "What type of wire should we use?" I explained that if we were to use a common gauge of copper wire, the resistance per centimeter is so low that we would need several hundred feet. Obviously we would have to use a different metal, so I closed the discussion by asking students to think about what causes resistance in a wire.

The next few days were reserved for a discovery type lab (Appendices IV-A, IV-B) in which students were asked to examine the relationships between the length and thickness of wires and their resistance. They accomplished this by first making Play-Doh "snakes" that they used for wires and then, probing the wires with a multi-meter, they recorded (Tables I-A , I-B) and graphed their results. The graphs were then analyzed to derive the relationships in the resistance equation. This activity is based on a lab I had read about a number of years ago. I remembered the basic set-up, and the concepts were simple enough that I merely bought a can of Play-Doh and played with it long enough to get a working idea. I then wrote up a lab worksheet for the equipment I had available.

V. Resistance within a wire:

After performing a lab on the concept of resistance, we returned to the question, "What causes resistance within a wire?" Using a traditional lecture/discussion format (Appendix V-A) we listed what factors have an effect on resistance and went into great detail as to why. For the objectives that I wanted to accomplish within this lesson, a lecture/discussion method works best because there is a significant amount of new material to present, much of which was unfamiliar to the students.

Before starting the unit, I had an idea for a demonstration device that would show the effect of rising temperatures on resistance, but I couldn't find the time to build it. When describing what I wanted to build to my students, one of them suggested that it sounded like the Plinko board on the game-show "The Price Is Right". The Plinko board is a flat slab, about the size of a pool table, tilted upright and embedded with evenly spaced wooden pegs. A Plinko chip, about the size of a hockey puck, is placed flat against the board and released. As the chip slides down the board, it rapidly bounces off the pegs in random directions much like electrons within a wire. I asked the students to imagine what would happen to the rate the chip "fell" if someone were to shake the Plinko board while the chip was still sliding. This is analogous to what happens as electrons try to move in one direction through a wire. If the pegs, which represent the atoms within the wire, move faster, the rate of travel for the chip is impeded. The story worked well enough that, until I can build the device, I'll continue to use it.

In the latter part of the lesson, we went back to the question of how long we needed to make the wire in our heating coil to get about 70 Watts of power. The problem is that in order to know the amount of power dissipated as heat, you need to know the resistance in the wire, but the resistance changes as the wire in the coil heats up. Therefore, it became necessary to know about the concept of resistivity and to introduce a formula for calculating resistance in a particular kind of wire at a particular temperature. The result of this boils down to the idea that resistance in a wire is proportional to the square root of the Kelvin temperature. This relationship was then used to determine that our wire needed to be about 156 cm long if we planned to use #20 gauge Nichrome.

On day six, after reviewing the relationship between resistance and temperature, wire was cut for the students. With the help of an overhead, (Appendix V-B) students were shown how to turn that wire into a heating coil and wired it into an 18 Volt transformer. (The concept of transformers was introduced in the previous unit.) We then tested the wires to see if they would heat up and used the remainder of the period for in class work on a homework assignment (Appendix V-C).

VI. A New Way To Measure Temperature:

Having built heating coils to power their ovens, I started the lesson by asking the students how they could monitor the temperature inside their ovens so that they wouldn't burn the cookies they were going to try to make. Several suggestions were fielded, written on the board, and then we analyzed the strengths and weaknesses of each idea. Eventually students were led to the realization that a thermocouple would probably be the best way to monitor temperatures inside their ovens. The point of this discussion was to introduce the concepts of thermodynamics used in thermocouples (Appendix VI-A) and lead into a lab (Appendix VIII) where students build their own.

Thermocouples make use of a principle of Physics known as the Seebeck effect (discovered in 1821) wherein electric current flows through a closed circuit of two dissimilar metals when one of the junctures is heated with respect to the other. The explanation of why this occurs involved some in-depth concepts and a fair bit of new terminology when covering the concepts of band theory and Fermi levels. Although the material offered in this discussion was quite challenging, by presenting it slowly and breaking down the concepts using simple laws of motion, I felt that it was accessible to the average Physics student. On the first day of this lesson, the focus was more on an explanation of what a thermocouple is and why electrons move within them. On the second day, after reviewing what was discussed previously, I presented an analogy to help explain how thermocouples work by way of a demonstration device known as a convection tube. This demonstration, which makes use of an overhead transparency (Appendix VI-B), consists of a current being produced by heating one side of a circular tube filled with water. Time at the end of this class period was reserved for a quiz on the concepts and skills used in the Play-Doh lab (Appendix VII).

VII. The Thermocouple Lab:

Now that the principles of thermocouples had been covered, it was time for students to start building their own. This activity is an original lab developed during my research summer (after briefly reading up on the subject) solely on the premise that, "it doesn't look all that difficult, let's build it and see if it works". After a day and a half spent rounding up supplies from hardware stores and the Physics department, it only took about an hour to get my first thermocouple built. A few hours after that and I had collected my first set of raw data which, once graphed, far exceeded my expectations. Of the projects developed during my five weeks of thesis research this one went the smoothest by far. As it turned out though, conceptually, it was the hardest project to get a handle on. While trying to write lesson plans for a lecture that would explain the basics of thermo-electrodynamics at a level a high school aged student would understand, I was forced to learn the material better myself.

During the lab, entitled "Physics Even a Biology Major Could Love" (Appendix VIII) the first day was spent completing the wiring and soldering needed to assemble a basic thermocouple. After a brief test to see that it worked, there were a few questions on the lab handout that required the students to do some higher-level thinking. One asked that they predict which direction the current would flow in their new thermocouple. Another asked why, when hooked to a battery, one juncture heated up while the other cooled down.

The second day of the lab was set aside for the collection of data, which was used for calibration. Even with a working thermocouple, the readings that the students obtained from their multi-meters were in voltages, and they still faced the problem of translating this information into units more relative to baking, namely degrees Fahrenheit. This was done by taking readings in samples of water ranging from boiling hot to icy cold using both a standard thermometer and their thermocouples. On the third day of the lab the students charted the data collected (in water) and extrapolated the line to temperature ranges not measurable with standard mercury thermometers (typical oven temperatures). This part was completed in our school computer lab and gave students a chance to work with spreadsheets and graphing software.

VIII. Amaze and Delight Your Friends:

The third week of this unit was devoted to the building, testing, and use of the Sneezy-Bake Oven. Following instructions in the lab (Appendix IX), two days were needed to get the ovens mostly completed. The instructions were fairly specific, so the role of the teacher was mostly to trouble-shoot. Part of the third day during this week was used to administer a vocabulary quiz (Appendix X), and the remainder of the day to give the students time to bring their ovens up to temperature and fix any minor problems.

On the following day it was time to don aprons and make the cookie-dough in preparation for our "take-off on the bake-off". One of the stipulations for the cookie-baking contest was that the dough had to be made from scratch and impounded overnight. I provided milk and eggs, and students were required to bring all other ingredients as well as bowls and spoons. Each group also had to come up with a name for their cookies, which was used to label the dough and identify their group. This activity occurred in our Resources room because it has better sinks and a refrigerator. On the day of our bake-off each group received a small plate and wrote their cookie name on it for judging purposes. They then had 45 minutes to produce as many cookies as possible for submission to the judges. At the time of this study, the panel consisted of myself, the building principal, and the manager of our Food Services department. Cookies were judged on taste, texture and appearance, and the winners received a small amount of extra credit.

IX. The dawn of the digital age:

In the first two days of the fourth week we returned to a lecture/discussion approach for the start of the next major section of this unit, extending the discussion of consumer electronics to computers. The second section dealt with studying the behavior of electrons within semimetals, and with the explosion of technology that has resulted from discoveries in this field. The first of the lectures (Appendix XI) was somewhat of a history lesson that traced the development of counting machines from the abacus up to the first computers. At the end of the period we discussed the huge advances made in video-game technology since the introduction of "Pong". Very few of my students realized that their parents were born before video games, hand-held calculators, and home computers became commonplace. The second day of lecture during this section (Appendix XII-A) got into the crystalline structure of semiconductors such as silicon and described how their special properties are responsible for the development of smaller, faster electronic devices.

During the middle of this week, I had scheduled a lab (Appendix XIII) adapted from scitoys.com, a website that lists building plans for science toys. The lab provided instructions for the building of a solar battery, and is a practical application of Einstein's photo-electric effect. It also gave the students a break from taking notes, for on the next day we returned to the topic of semiconductors and continued with an explanation of how transistors work. As a demonstration on the uses of transistors, I showed how they are used to amplify the weak electrical signals produced by a homemade metal detector.

X. Good Intentions

According to my original plan for this unit, on the last day of the fourth week students were scheduled to begin their big project for the third marking period. In keeping with a consumer electronics theme, the project (Appendix XIV) involved having students build a homemade version of an electrical appliance or toy. The goal with this activity was to have students develop the practical problem-solving skills that we usually refer to when we say someone is "good with their hands". The project was intended as a capstone to end the unit, with some of the work done in class, but the majority done at home. It was supposed to be completed after the final test, however, due to the large amount of time the project entailed, it was the first casualty of a need to shorten the unit in time for the end of the third marking period.

XI. Wrapping Things Up:

The last two days of instruction for the unit were lecture/discussions designed to dispel the mystery behind what makes computers work and to show that a computer is merely an intricate arrangement of very simple devices. In "Generation 01011000" (Appendix XV), students learned the basics of binary code and were shown the inner workings of devices that use transistors to convert signals from analog to digital and vice versa. The goal was to impress upon students that when a computer "reads" information, such as when a color-matching device is used to mix the same shade of paint from a fabric sample, the input device on the machine is merely generating an electrical signal and converting it to a number which gets processed in much the same way as in a calculator. In "The Ants Go Marching One By Zero"(Appendix XVI), I tried to show how transistors and capacitors are used to store memory in a computer and also how a computer adds two numbers together. This was followed by a worksheet (Appendix XVII) that reviewed concepts from the previous two days and included a binary maze in which students used logic gates to add two numbers.

The final few days of the unit were left somewhat to the whims of the schedule for that particular year. I had a day planned for the final vocabulary quiz (Appendix XVIII), which was also the day the review sheet for the unit test (Appendix XIX) was to be handed out. The review sheet included the vocabulary used in the matching on the test, a few sample questions, and a warning about the essay portion. Another activity was an hour long PBS film on the development of transistors which, in the future, could be included if the schedule permits. The final test itself was exactly the same as the Pretest, which bothered me at first because I figured that the students would recall everything they had read before and that everyone would "ace" the test. This was not a problem though because, by the end of the unit, I myself couldn't remember what specific questions were asked. After taking the test, the students were to fill out an exit survey (Appendix XX). This, however, did not happen right away. The surveys were forgotten in the rush to get tests corrected before the end of the marking period and were not handed out until a week after classes resumed; another casualty in the fight against time.

EVALUATION

I. Laboratory Analysis:

Of the roughly five weeks needed to complete this unit, nearly half of those days were spent in laboratory. This makes evident the fact that the labs are the major focus and the major draw. It was my intention to use the students' sense of excitement over a "fun" lab to lure them deeper into the study of physics than they might otherwise go.

The first of four labs, "Playing Around with Resistance" (Appendix IV-B), was a discovery lab in which it was up to the students to explore the relationship between the dimensions of a wire and its resistance. Based on my own observations, the students seemed to like the lab, probably because they got a chance to play with Play-Doh. Although I was pleased with the results of this lab, there are a few changes I would make so that it goes smoother in the future.

It is important to bear in mind that many of the students are unfamiliar with using the equipment in these labs. For most, this was the first time they had used a multi-meter, and since our classroom models are not auto-ranging, every time the reading would rise above the setting they had it on, the screen would show a dash. The students assumed this meant the multi-meter wasn't working and that their set-up was wrong. Some students needed help with tasks as simple as connecting and taping two bare wires. There are so many little tricks to facilitating hands-on work (and they only come with experience), that labs take more time with student learners. For this reason, to save time, I've added a handout (Appendix IV-A) with a ten-centimeter grid already printed on it.

The Thermocouple Lab (Appendix VIII) is one of my favorites partly because it works so well, and partly because the end product is so useful. A well-made thermocouple not only works fast, but it can also be more accurate and work at higher temperatures than normal thermometers. Using the data for voltage and temperature from Table II, the students made a graph and extrapolated the line created into the range of the temperatures they would achieve with their ovens. This gave me an opportunity to validate the use of Seebeck coefficients by comparing the experimental voltages that were obtained to calculated values.

Needless to say, the Sneezy-Bake Oven lab was the highlight of the unit. It was obvious that the students were excited about building the ovens just by the number of times I heard, "Are we working on our ovens today?" There was also a lot of "talking smack" about whose cookies were going to win the bake-off. After the end of the unit, during parent-teacher conferences, I set up one of the ovens and baked cookies between visits. When students came in, they would literally drag their parents over to see what they had been doing in class. In addition, some very good questions arose over the engineering aspects of the ovens. These came from students wanting to fine-tune their ovens in order to win the contest. One group wanted to add more metal to act as a heat sink and keep the temperature inside more constant. Another group built an "Air-Bake" pan to help keep their cookies from burning on the bottom since that is the side the heating coil is on.

The last lab of the unit was the Solar Power Lab (Appendix XIII), which made a nice break in a string of lecture/discussions. It gave the students a chance to work with Bunsen burners, and it was also fun for the students to watch the black pieces of cupric oxide coating jump up from the copper plates. The lab nicely demonstrates the photoelectric effect because it works well, but the students had to rush to finish near the end. This makes it important to start right away and have everything ready to go. There are also some good questions to answer in the write-up for the lab, one of which makes the point of how little power is produced by even a large solar panel.

As usual, the homework scores for laboratory write-ups revealed little about how much individual students understood of the concepts being taught. Throughout the last several school years I have noticed that if students are given questions to finish and hand in the following day, unless they are given time in class to work, sometimes as much as half the class will fail to complete the assignment on time. In the past I have allowed students to fail in such cases. However, for a few students this punishment has no effect. Some are simply not willing to do the work necessary, and when their grade drops as a result they simply drop the class. On the alternate side, if students are allowed extra time to complete an assignment I end up with five original answers out of a class of twenty. With problems involving calculations it is relatively easy to come up with several different keys and force students to do their own work, but with essay style questions I have yet to find a suitable solution.

II. The Old School Style:

Given the effectiveness of the lecture/discussion format, it would be difficult to cover a significant amount of material without relying at least in part on this method. The content of a few of the lectures within this unit was very challenging, and this is something that worried me with the group I had. Each class taught is a little different, and I would have to describe the students I had during the year of this study as "lukewarm". There were no really exceptional scholars and no real problems at the lower end. In terms of grades for the year, it wasn't unusual for 80% to 90% of the class to fall within a range of ten percentage points. Throughout the more difficult lectures there were a core of students who stayed focused, but also some that refused to be pulled into discussion no matter what I did. To some extent it depended on the day. During "If You Can't Stand the Heat" (Appendix VI-A), it was like pulling teeth to get a response from the class, but the very next day the students seemed to enjoy the convection tube analogy and there were a lot of good questions.

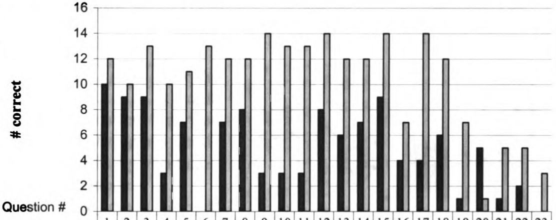
III. Teacher, test thyself:

Given my experience with teaching seniors, I had expected test scores in the second semester to drop, and indeed they did. The students were completely unprepared for their first quiz, "Fight the Power" (appendix VII). I'm not sure whether it was for lack of adequate warning or an early onset of "Senioritis", but more than once I overheard comments to the effect that "second semester grades do not matter". Scores on the next quiz, Termiknowlogy (Appendix X), were much better. In fact the average was an 80.6%. This might have been due in part to students trying to make up for their scores on the previous quiz. The class never had the chance to take the third quiz. Towards the end of the marking period, there were three unexpected interruptions that cost valuable time: a Spanish field trip, a senior class meeting scheduled the hour I had Physics, and an anti-drinking assembly that was announced to everyone the day before. In the scramble to finish the unit before Spring Break, I decided to use the quiz as a review sheet.

As stated earlier, the students were given the same questions as both a pre-test and post-test. (Appendix II) The scores did improve, of course (a 33.3% average to a 69.3% average.), but not as much as I'd expected.

Figure I

Pre-test vs. Post-test



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
■ Pre-test	10	9	9	3	7	0	7	8	3	3	3	8	6	7	9	4	4	6	1	5	1	2	0
□ Post-test	12	10	13	10	11	13	12	12	14	13	13	14	12	12	14	7	14	12	7	1	5	5	3

If you look at the scores for questions #1-19, you can see that on most questions there is vast improvement. This is mainly because these questions deal with terminology, some of which would have been unfamiliar during the Pre-test. If the questions had answers that students could take an educated guess at or that concerned topics covered in the previous unit, the scores on the Pre-test were generally above 50% correct. On question #20, a multiple-choice question dealing with resistivity, students did worse on the Post-test than on the Pre-test. In defense of my students though, this was a poorly worded question and a tricky one to answer. When going through the formula for resistivity in our lecture, I did not specifically mention the size of atoms (choice b.) as a factor even though it does have an effect.

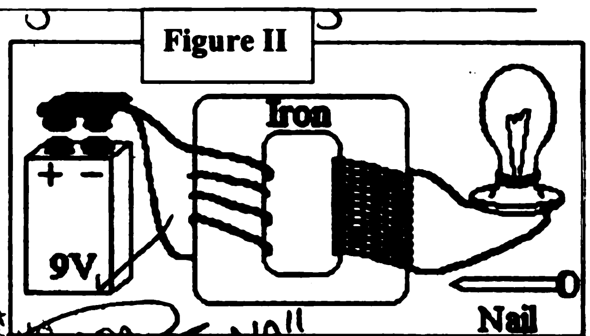
The results for questions #21-23 were a disappointment. Question # 21 is a simple recall question that asks what the letters LED stand for. Not an important concept, but a detail that I would have thought most students would pick up. In question #22 most students continued with their belief that the transformer (Figure II) would work when connected to a battery. If I could afford to purchase a classroom set of AC power supplies I would have students experiment with building their own transformers to address this problem.

Student sample

22. L[...]m to the right [...]t would happen if the battery lead were connected. Also give a good explanation of why you think this would happen.

Event- The nail would stick to the iron & light would turn on ⟸ No!!

Explanation- The flow of electricity would turn the iron into an electromagnet, attracting the nail.



Something else that I noticed was that there were concepts and equations from the previous unit of which students gained a better understanding by virtue of using them again during this unit. On the final test of the electricity unit, there was the following question:

The amount of [power] dissipated by a wire is equal to the current squared times the resistance. This is known as Joule heating.

Three out of fifteen students got this one wrong even though the equation was listed on the test. By the post-test for Consumer Electronics, 14 out of 15 got a similar question (#12) correct without any equations listed. However, when faced with a higher-level thinking question involving the same concept (#23), many could recall the equation in their answer, but few understood the relationship between the variables at a deep enough level to answer the question correctly.

Figure III **Student sample**

A thermocouple is two dissimilar metals, binded at each end. It works by cooling down one end, while applying heat to the other, producing an electric current. This is known as the Peltier effect. The Peltier effect takes place when the one end is heated, and the other end cooled. The end that is cooled causes the electrons in the Iron to move into the copper because copper has a lower Fermi Level than Iron does. When the electrons move down to copper's Fermi Level, the give off the extra energy as heat. The opposite is happening on the other side of the thermocouple. The heat is being absorbed by the electrons in the copper, allowing them to "jump" up to Iron's Fermi Level.

Another effect that can be achieved with a thermocouple is known as the Seebeck effect. It is caused by forcing a current through a thermocouple. This causes one end of the thermocouple to cool down because it is absorbing heat to allow it's electrons to move up to a higher Fermi Level. The opposite is occuring on the other end of the thermocouple. This end is getting hotter because electrons are giving off heat so they can move down to a lower Fermi Level

Seal

On the essay portion of the test, there were some very good answers on the whole (Figure III), especially considering that before the unit an informal poll showed that not one student knew what thermocouples were used for. In fact the student who scored highest on the post-test was the only one to even venture a guess at this question on the pre-test. The most common error on this portion was in the use of the vocabulary words as can be seen in the essay sample above. It's fairly easy to match up a word to a definition, but to be able to incorporate it into writing takes a deep understanding.

IV. Survey Says...

In evaluating the student responses to the exit survey (Appendix XX), I suspect that the answers I received lost some spontaneity due to the fact that they were administered two weeks late. It should also be pointed out that since the project (the 4th choice for questions A-C) was not completed the students were told to disregard that option for those questions. In answer to the first question (A), "What was the best part of this unit?", the number one answer was labs. One of the reasons given for this choice was, "I got sparks to shoot out of our oven and our cookies were actually edible." Answers to the next question (B), "what part of the unit do you feel you learned the most from?", were pretty evenly split. It was interesting that two students put nearly the same reason for two different first choices. One wrote "I learn better when its right in front of me" about the worksheets and another wrote "It's easier for me to understand stuff if I can see what I'm doing" about the labs. The answers for which part was the most frustrating were almost evenly split between labs and lectures. One person wrote, "Definitely lecture at least for a few of the notes. I understood everything when we were figuring how long to make the wires, but when you started talking about conduction levels it went woosh!" Drawn in the margin was a picture of a head with an arrow over it.

Question A	1st Choice	2nd Choice	3rd Choice
Method of instruction			
Classroom discussion/lecture	5	7	3
Laboratory activities	10	3	2
Worksheets and problems	0	5	10

Figure IV-A

Question B	1st Choice	2nd Choice	3rd Choice
Method of instruction			
Classroom discussion/lecture	7	3	5
Laboratory activities	4	6	5
Worksheets and problems	4	6	5

Figure IV-B

DISCUSSIONS AND CONCLUSIONS

I. Looking Back...

Overall, I am happy with the effectiveness of the unit. There was a lot of planning that went into the progression of lectures and activities, and I'm pleased with the way they came together. Other than the accommodations that had to be made at the end of the unit because of scheduling problems, it seemed to flow well. It was definitely a lot of fun to teach and I'm looking forward to doing it again next year.

While only a small portion of this unit was taught from a Problem-Based approach, it was successful enough to alter my overall teaching strategies. Not only do I plan to rewrite another portion of this unit, using this method, but as I rewrite sections of both my Physics and Chemistry curriculum I plan to include Problem-Based activities in them as well. On the day of the first lesson, when the idea of building ovens was proposed, and the students were asked for suggestions, the time seemed to fly by. The student-dominated discussion went very well with lots of participation and there were several very good ideas put forth that I had not considered. Some of these ideas included adding a rheostat to our ovens to control the power supplied (I've already ordered a classroom set for next year), adding a fuse to keep the coil from overheating, and making a window so that we could keep an eye on our cookies as they bake.

One thing I would like to do differently is to rewrite the introduction to the handout (Appendix III-A) that goes with the discussion. I have never really been happy with the way the introduction sounds, it was meant to be humorous, but just comes off flat. I try to use humor as much as possible in worksheets and handouts as a means to alleviate some of the dread of a new homework assignment, but humor is not something you can simply turn on when you want to. It may take until the second or third rewrite before I'm happy with it.

Another thing I noticed during this unit was that even though some of the labs were lengthier and included more complicated instructions than labs from previous units, it didn't seem that I spent as much time answering ill-conceived questions. Usually a great deal of my time on lab days is used running from group to group answering questions that could have been avoided if the person asking the question had taken a few seconds to think first. I attribute much of this to the fact that the students started this unit with a problem-solving attitude. Perhaps by involving more Problem-Based activities during Chemistry in their junior year, I might see a difference in attitudes earlier in my Physics classes.

The highlight of the unit for me was of course building our ovens and the lessons that led into that lab; probably more so because there were no assurances that the ovens would even work. About halfway through the five weeks of my summer research, I was worried that they might not, and in that case I would have to come up with something else to do. Also once the school year started, I had to convince my superintendent and school board to fund the project. If they hadn't supplied the $1200 needed for multi-meters, transformers, and other equipment, it would have put me in a tight spot. In the end though, I'm glad that I tried something innovative rather than pursuing a safer idea.

Even though I started the Sneezy-Bake Oven project using Problem-Based Learning, by the time of the final construction, the lab followed more of a cookbook technique. The instructions are fairly specific and the student's ovens ended up looking very similar. It is not that I thought the students would be incapable of developing a working model on their own, but based on my own experience I knew it would be difficult under the constraints of time and equipment. Also, I had originally planned to give them an opportunity for open-ended experimentation at the end of the unit, only with a Project-Based not Problem-Based approach.

As stated earlier, my original schedule included a large building project in which students would be required to construct a working model of an electronic appliance or toy. Each quarter my Chemistry and Physics students are given a Marking Period Project assignment that counts as 5% of their grade and this building project would have counted for the third marking period. I had then intended to have each group present their project and the basic concepts they had learned at our annual Science Exposition. (Each year my Chemistry and Physics students put on a science fair for the third-grade classes.) Again, this did not happen due to time constraints.

Overall, the implementation of Problem-Based Learning techniques was enough of a success that it will undoubtedly become a larger part of my methodology as I rewrite curriculum for future years. More specifically, for next year I am going to turn the calibration of our thermocouples into a problem-based discussion. I expect that having students come up with their own solution to this problem will make their results all the more significant.

II. Room for Improvement:

Somewhat vexing during this unit was the poor performances on quizzes and the final test. Although I realize that it was my first attempt at teaching this material, the results were disappointing nonetheless. To change this for next year, I would like to add extra critical thinking questions on labs or combine several of these questions into a separate worksheet. For instance, since teaching the SneezyBake Oven lab, I have added a fourth page consisting of problems that will help students to review testable material and that will occupy any group finishing early. My feeling is that the students need more practice with thinking through multi-step problems before they take the final test. Also, I plan to give them more help in developing the essay. One might argue that the students are simply cramming in material to regurgitate on the test, which may be somewhat true. However, the important point is that not only are they forced to learn how to assemble an effective argument, but according to the Constructivist ideas regarding personal experience, somewhere along the way the content is going to sink in as well.

In terms of classroom management I had several days where I felt rushed at the end of the period. Usually this was because at the beginning of class I would think of things I had forgotten to do and scramble to get them ready. This means that by the end of the period, I was hurrying to help every lab group finish and clean up, and I didn't have time to help students with the questions at the end of the labs. This is a golden window of opportunity in terms of learning because the lab is still fresh in their minds and these questions are some of the most thought-provoking. In the future I will try to budget my time more wisely. Of course, merely the experience of teaching the lesson once has taught me enough to make things go smoother next year. Case in point, I doubt that I will show the movie "Transistorized!" again. Although it was well done and I found it interesting, somewhere along the line you have to strike a balance between a thorough explanation and too much of a good thing.

One more area with room for improvement is the traditional lecture/discussion. Some of the material that is covered in lectures could be presented effectively in other ways as well. For next year, I would like to turn "Word Processing 1.0" (Appendix XI) into a web-based research worksheet, and to improve the next day's lecture/discussion, "Solid-State Physics" (Appendix XII-A), the whole lesson, overheads and all, could be turned into a power-point presentation. I think the movement of electrons within diodes and transistors could be visualized much more clearly if it were turned into a short animation. The same could be said for topics covered in "The Ants Go Marching One by Zero"(Appendix XVI). Although I was amazed that when we went over the diagrams of logic gates and transistors, one of students who had been on the fringe in terms of his attention span woke up and asked lots of questions. This was surprising enough that I had written, "Who would've guessed?" on my observation sheet for that day.

In revising my plans for the next time I teach this unit, this is an area that I wish to spend more time on simply because there are so many good examples of how this technology is employed. I would also like to build more lecture-friendly demonstration devices to go along with the discussion of how electrons move in diodes and transistors. These would consist of angled wooden display blocks with circular "scoops" bored out in a pattern resembling the crystalline structure of silicon. Wooden balls would fit into these "scoops" and represent valence electrons. Where impurities in the crystalline structure exist, there would either be an extra hole (scoop) or an extra electron (ball). By "moving" these holes or extra electrons, I could simulate the behavior of n and p-type semiconductor materials.

III. Looking Ahead...

In retrospect, dropping the marking period project (Appendix XIV) left the unit feeling unfinished. I would have liked for that section to lead into a tangible "pay-off" of some kind for the students, so for next year I will look at rearranging units so that it can be included. Another option for a project-based assignment, one that would be easier to implement, is to split the class into groups and have them compete to see who could design the best metal detector. They would be instructed on the basic principles and shown a simplified version, but only enough to get them started. Considering that they wouldn't be allowed to use kits, the students would encounter many good engineering challenges in the course of building their design. They would also have a chance to study magnetic fields and encounter a practical use for transistors. The pay-off could be a treasure hunt for real gold using their homemade detectors. With sponsorship, the treasure might even be enough to generate some real excitement. Once the groups were finished with the building portion, I could hand out treasure maps complete with riddles to clue the students in to the general location of the buried gold.

Perhaps the most important lesson that I have learned in developing this unit is realizing what devoting a large amount of time to curriculum development can do. It has improved my teaching both in terms of ability and content, and as an added side effect, the better my material is, the more enjoyable it is to teach.

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APPENDIX I

RESOURCES USED FOR DEVELOPING CONTENT

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APPENDIX II

CONSUMER ELECTRONICS

(It's not as geeky as it sounds.)

Name ____________________

A. Match em' and Scratch 'em:

a. AND gate
b. Seebeck effect
c. capacitor
d. photo-electric effect
e. Ohm's law
f. integrated circuit
g. multimeter
h. transformer
i. Peltier effect
j. thermistor
k. n-type silicon
l. thermocouple
m. Fermi level
n. forbidden gap
o. conduction band
p. resistivity
q. transistor
r. p-type silicon
s. valence band
t. EOR gate
u. analog signal
v. semiconductor
w. binary signal
x. marks the spot
y. NOT gate
z. diode

1. A(n) _____ is a device that stores charge as a potential across two parallel plates.
2. Most electrons around atoms in a substance are bound within the _____.
3. The difference in temperature between the cold juncture and the hot juncture generates an electric potential in a device known as a(n) _____.
4. The _____ represents the potential energy of electrons in the highest occupied orbitals of an atom.
5. A(n) _____ is a device that uses sandwiched layers of n-type and p-type semiconductors as an electronic switch or amplifier.
6. Only when two high voltage signals come into a(n) _____ is a high voltage signal passed on. If either a high and a low, or two low voltage signals enter, a low voltage signal leaves.
7.–8. A(n) _____ is sent along as a voltage that gradually varies from high to low, while a(n) _____ is coded as discreet pulses of high or low voltage.
9. _____ is proportional to the thermal velocity (or the square root of the absolute temperature) of atoms within a material.
10. A small sensor in your television makes use of the _____ to detect signal from your remote control.

B. True/False:

_____ 11. The resistance within a wire increases as the wire gets colder.
_____ 12. The power lost due to joule heating in a wire is equal to IR^2.
_____ 13. On a multimeter or power supply, electrons move from the red terminal (+) to the black (-), while current moves in the opposite direction.

_____ 14. Wiring two batteries in series will double the voltage.

_____ 15. A toaster wire gets hot because it has an extremely low resistance compared to the leads to which it is connected.

C. Multiple Choice:

_____ 16. What element might most likely be used to dope n-type Silicon?
a. Nitrogen b. Aluminum c. Germanium d. Phosphorus

_____ 17. What is the binary equivalent of 00110110?
a. 38 b. 54 c. 66 d. 82 e. 108

_____ 18. Which of these devices make use of the photo-electric effect?
a. Photocopier b. Light bulb c. Stereo speaker d. VHS tape

_____ 19. A Copper wire is connected across the terminals of a 12V battery and has a current of 12 Amps. Assuming that Ohm's law is obeyed, what is the new current when the wire is replaced by a Copper wire with twice the diameter that is also twice as long?
a. 3 Amps b. 6 Amps c. 12 Amps d. 24 Amps

_____ 20. Which factor does NOT affect the resistivity of a material?

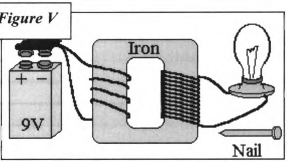
a. The thermal velocity of its atoms.
b. The mass (size) of its atoms.
c. The temperature of the material.
d. The length of the wire.

D. Assorted problems:

21. What does LED stand for? ______________________________

22. Look at the diagram to the right and describe what would happen if the battery lead were connected. Also give a good explanation of why you think this would happen.

Figure V



Event- ____________________
____

Explanation- ____
____
____

23. What happens to the power output (Energy converted to heat in Watts) of a heating element as you increase its length? ____________________
Give an explanation why- ______________________________
____
____

E. Stands for Essay of Course:

Use the box below to create a diagram, and use it to explain **what a thermocouple is used for** and **how it works**. In order to get full credit, you must use at least three of the words from the matching section of the test correctly. (Only applicable words will count.)

APPENDIX III-A

"Nothin' Says Lovin' Like Somethin' From the Oven"

Name ____________________

At this point you may be wondering, "Why am I challenging myself by learning all this stuff about electricity? What's the point? What's in it for me?" In answer to these questions, you are doing it to satisfy your needs. No, I'm not talking about a need to satisfy your innate curiosity towards the natural world, but rather about your basic needs; the stuff you can't live without. Food is the most immediate human need, followed of course by shelter and clothing. However, the most important thing about the latter two is that you need to keep warm, so in a sense clothing and shelter are really optional. Let's face it, if you were stranded on a tropical island, as long as you were warm and had enough to eat, who wouldn't be content wearing nothing but a loin cloth? But would you really be happy? Supposing you could make fire, you could satisfy two needs at once. Not only would you get warmth, but you could cook your food as well. Even so, cooking over a camp-fire leaves something to be desired. Everything tends to get burned on the edges and smell like barbecue. This is why man harnessed electricity. (A much more civilized option.) Soon afterwards came the development of the electric oven, and, in a never-ending pursuit of happiness, the chocolate chip cookie. Can you live without chocolate chip cookies? Probably*, but the most important human need is love, and supposing that you were stranded on a tropical island, warm chocolate chip cookies is about as close as you're gonna get. (Especially if you run around all day in a loin cloth.)

Therefore…in order to deepen your appreciation for the modern conveniences we all take for granted, your next project will involve building an oven out of a Kleenex™ box. (Hence, we will call them Sneezy-Bake Ovens.) You will then prove your engineering and culinary skills by using your oven to enter your favorite recipe for homemade cookies in our annual take-off on the Bake-Off.

Think for a few minutes, and then let's discuss how we should go about doing this.
What should we use for a heat source?

-

-

What should we do to keep the heat in?

-

-

How can we keep the box from burning?

-

-

How can we control the temperature so we don't burn the cookies?

-

-

What other aspects should we consider?

*This is assumed to be theoretically possible, but we have yet to encounter any real proof.

APPENDIX III-B

Lecture Notes for "Nothin' Say's Lovin'…"

Hand out introduction sheet and have student read aloud. Have students think about questions for a few minutes and then copy suggested answers on board. *Try not to coach ideas. Have one student keep track of all suggestions.

All right then, let's answer the first question. How are we going to heat our oven?
-Can't use lightbulb.
    *Don't want to have to deal with patent infringement.
    *Lightbulb would take up too much space.
-Other ideas?
-How do they heat a normal oven?
-Where does this heat come from?
    *Joule heating (brief explanation)
-What type of wire?
    *Something that's not going to rust or burn.
    *What other properties?

How are we going to measure how much heat we provide?
-What units do we use for heat energy supplied (power)?
    *What's a Watt? 1 J/s or N×m/s or kg×m^2/s^3
-How many Watts?
    *The EasyBake Oven (1963) from the 80's used a 100 Watt lightbulb.
  Our heating coil will be more efficient at creating heat so we'll shoot for about 85 W
How are we going to get around a 85 Watts of heating power?
-What is the formula for how much power an electrical wire supplies?
    *$P=IV$ and $P=I^2R$ (What are these units?)
    *What are Volts? J/C or N×m/C
    *We are going to be using Transformers that step down the 110V from the wall plug to 18V (We'll have to check this to be sure. The first transformer I bought operates at out about 19.5V)
        **Actually we will be using AC power so we will be using V_{RMS} (draw)
-Based on this, how can we get 85 Watts?
    *What current will we need? (4.36 Amps)
    *What resistance will give us that current? (4.47 Ohms)

The resistance is going to come from our wire heating element, so what kind of wire should we use and how much?
-We want a wire with a fairly high resistance. Why?
    *We don't want to have to use too much of it or our element will be too big.
        **Medium gauge copper wire has a resistance so low that for 4.47 Ohms, you would need about twice the length of a football field.
-What else?

Here's the big question of the day: What determines a wire's resistance? Think about it.

Playing Around with Resistance

APPENDIX IV-B

Playing Around With Resistance

Name ________________________

Introduction:

Everyone knows that Play-Doh® is lots of fun, but did you know that it has been around longer than your parents? Play-Doh is a non-toxic reusable modeling compound that was developed by Rainbow Crafts of Cincinnati in 1956. At first it was only sold in one color and size, an off-white, 1 ½ pound can. Not much later, smaller colored cans became available and since then, over *TWO BILLION* cans have been purchased! If combined, the total amount of Play-Doh Compound manufactured since 1956 would weigh more than 700 million pounds, and if it were extruded through the Play-Doh Fun Factory®, it would make a "snake" that would wrap around the world nearly 300 times.

Of course what you probably don't realize is that Play-Doh makes a nifty wire for studying Ohm's law. Because of the high salt content and the presence of water, you can pass a small amount of current through the wires you make by rolling it into noodles. Today we are going to use this wonder compound to establish a mathematical relationship between resistance and some other factors.

You will need...

one can of fresh Play-Doh® brand modeling compound, a Voltmeter, a multimeter, two large nails, two small nails, a ruler or set of calipers, one or two 6V batteries, four alligator clips, a calculator, pen or pencil, and a sheet of paper.

Procedure:

1. On a sheet of paper, make two parallel lines about ten centimeters long and exactly ten centimeters apart. Between the two lines make smaller graduations at one centimeter intervals.

2. Use the Play-Doh to make a uniformly cylindrical wire (snake) about 15 cm long and exactly 1.0 cm in diameter. Try to get the diameter as close to 1.0 cm as possible. Make another snake with a diameter of 1.5 cm, and if enough dough remains, make others with diameters of exactly 2.0, 2.5, 3.0, 3.5, and 4.0 cm. (You will have to wait until you're finished testing the first few snakes to make the others.)

3. Set up the first snake for surgical probing as shown:

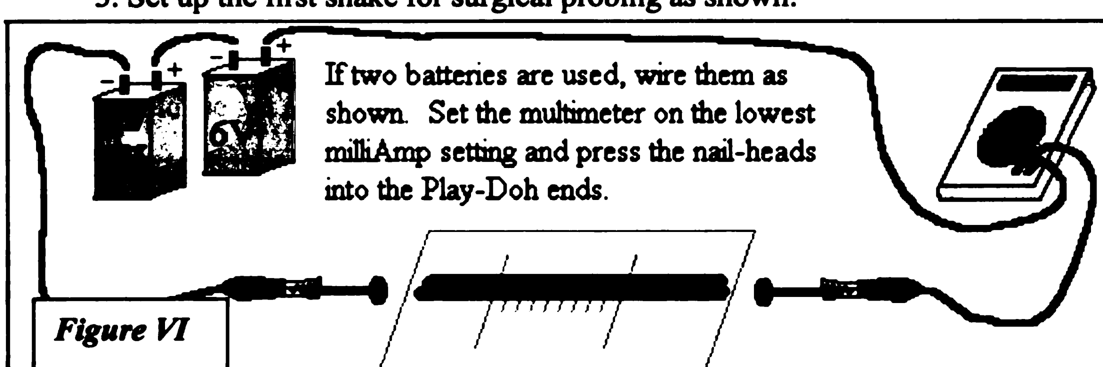


Figure VI

4. Set up the voltmeter so that the leads are connected to alligator clips. In the other end of each alligator clip, grip a small finishing nail with the pointed end out. These will be your voltage probes. Use the 0-1.5 connection posts on the Voltmeter, so that you can read the voltage accurately.

5. Take the first measurement by inserting the voltage probes ten centimeters apart and simultaneously recording both the current and the voltage. Read both to as many digits as possible. The probes will probably need to be motionless to get a steady reading. Once this is done, record measurements at each centimeter interval down to one.

Length	**Current (mA)**	**Voltage (V)**	**Resistance (Ω)**
10.0 cm			
9.0 cm			
8.0 cm			
7.0 cm			
6.0 cm			
5.0 cm			
4.0 cm			
3.0 cm			
2.0 cm			
1.0 cm			

6. With the other Play-Doh wires, take readings at only the ten centimeter length and record them in the table below.

Diameter	____________	Current (mA)	Voltage (V)	Resistance (Ω)
1.0 cm				
1.5 cm				
2.0 cm				
2.5 cm				
3.0 cm				
3.5 cm				
4.0 cm				

7. Use the data from the tables to make one graph that plots Length vs. Resistance and another that plots Diameter vs. Resistance. Be sure to label all units, scales, and give each graph a title.

What did you notice about the lines each set of data points make? ______________

____

____

How could we get a linear relationship for the second set of data? ______________

____

____

8. On the table, fill in a column heading that says ____________________ and calculate the values for each Play-Doh wire. Make another graph of this set of data vs. Resistance. Was there a linear relationship?

Write a verbal function statement that explains the relationship between each variable for the two graphs that gave straight lines. (i.e. When the Length of wire gets longer…)

1. ____

____

2. ____

____

APPENDIX V-A

Viva La Resistance!

Yesterday we asked the question, "What determines a wire's resistance?" We asked this because in order to make our Sneezy-Bake ovens, we figured we would need a heating element with a resistance of about 4.47 Ohms.

Let's start by asking "What does resistance mean?"

(Something that prevents an object from going forward.)

-What object are we talking about in this case? (electrons)

-What is it that is going to prevent current from flowing through a material?

-What does it take to prevent any motion? Remember your Newton. (a force)

*It is interactions with the electrons and ions in a material that cause all resistance. So anything that increases the amount of interaction (collisions) increases the resistance.

What will increase the amount of interaction?

1. Length (Why?)
2. Diameter (Why?)
3. Temperature (Why?) **[Joule heating demo] (pinball machine)**
4. Material (If we have two wires of the same length and diameter at the same temperature, why would the resistance be different?)

a. In electrically insulating materials like diamond or rubber, there are simply no free electrons to move the charge. In order for conduction to occur, some of the electrons must be in an unbound state called the conduction band. [draw] (A range of energies that electrons can have in a free state.) valence band (A range of energies [distances from the nucleus] that an electron can have and still be in a stable orbit.) forbidden gap (The difference between the largest amount of energy an electron that is bound to the nucleus can have and the smallest amount of energy needed for ionization.)

Figure VII

The activation energy or ionization energy for electrons in insulators is just too big for this to occur at normal temperatures. In semi-conductors and metals the energy it takes for an electron to break free from an atom (go into the conduction band) is much smaller.

*Coinage metals with "empty seat" -Much lower resistance

b. Also you have to consider atomic size and the number of free electrons.

-If you look at two wires of identical size, one made of large atoms and the other small, (DRAW) there are obviously more atoms in the wire made of smaller atoms. So what does this mean? What was our definition of temperature?

-If they are at the same temperature that means their atoms all have the same average energy and, if there are more of the smaller atoms, there is more energy in the collisions within that wire. (Think more pins in the pinball machine)

-Aluminum metal has around 3 free electrons per atom whereas most metals only have on average about 1-1.3. This means more collisions and higher resistance.

Here's the problem then:

We want our heating coil to have a resistance of 4.47 Ohms because we want a current of 4.36 Amps so that we provide around 85 Watts of heating power. **If the resistance of our wire changes as it gets hotter**, how can we know how long to make it to get 4.47 Ohms?

Wouldn't you know that there's an equation for this very problem? I'm sure you're all thrilled, but don't worry because it's not all that tough.

**You won't be required calculate number values with the following equations but I do want you to be able to recognize the relationships between the variables.

-To do this type of problem, you need to know about the concept of **resistivity**.
(Resistivity is a measure of the ease with which electrons move in a material.)
*If it is low, resistance is low. This is a direct relationship. If we add this to what we learned in the Play-Doh lab we get the formula $R = \frac{\rho \ell}{A}$. If the length is longer.... If the cross-sectional area is larger...

The classical formula for resistivity shows it is a function of both the material and the temperature.

$$\rho = \frac{m}{e^2 n \tau}$$

Where ***rho*** is resistivity, ***m*** is the mass of an electron, ***e*** is the charge of an electron, ***n*** is the free electron density in $^{\#particles}/m^3$, and ***tau*** is the time between collisions.

The time between collisions is equal to the distance the electron has to travel divided by its velocity. $t = \frac{d}{v}$ (makes sense right?) so $\tau = \frac{d}{V_T}$ where V_T is the thermal velocity.

The thermal velocity is simply a function of the temperature. (As it goes up...)

$$\tfrac{1}{2} m V_T^{\,2} = kT$$

Where ***m*** is the electron mass, ***T*** is the Kelvin temperature, and ***k*** is Boltzman's constant.

-Now let's simplify things. The values for *m* and *k* do not change, so really $V_T^2 \approx T$ and thus $V_T \approx \sqrt{T}$ so $\tau \approx \frac{1}{\sqrt{T}}$ since *d* doesn't change, and $\rho \approx \sqrt{T}$ since *m*, *e*, and *n* don't change. So if you don't switch wires $R \approx \sqrt{T}$

The classical formula for resistivity shows the resistance in a wire as proportional to the square root of the temperature, but this is not what is observed in real life.
According to the quantum theory, electrons act as waves. If the substance that they are passing through has a regular crystalline arrangement of atoms, then a collision with one of these atoms is unlikely. They move freely through with no resistance. Electron waves are only scattered if there are imperfections caused by impurities or defects in the crystal. At low temperatures, resistivity is dominated by the collision of electrons with these defects. At high temperatures, resistivity is dominated by the collision of electrons with

atoms of the material. This occurs because as the solid is heated more atoms vibrate out of their regular position in the crystal lattice.

-So if a metal has a lot of imperfections within the crystalline structure, it will have a higher resistance. [refer to Pinko story] This is why we will be using Nichrome wire. ------Nickel/Chrome alloy--more "impurities"—more collisions

In practice, resistivity in metals varies almost linearly with temperature according to the equation; $\rho = \rho_0[1+\alpha(T-T_0)]$ where ρ_0 is the resistivity at a reference temperature (T_0) of 20 °C and α is the temperature coefficient of resistivity for that metal. (For Nichrome it is 4.0×10^{-4}/°C.)

Since $R = \frac{\rho \ell}{A}$, by multiplying both sides by $\frac{\ell}{A}$ we get $R = R_0[1+\alpha(T-T_0)]$

Let's use this to figure out how long to make our wire.

---First let's measure out a little more than a meter of the #20 gauge Nichrome wire we will be using, and we will use a multimeter to measure the resistance over a length of 100 cm. Convert this to Ω/cm.

-Also, we will need the approximate temperature of the room in Celsius. (around 20°)

-When the wire is heated by our transformer, it will operate at somewhere around 1400° Fahrenheit. What does this correspond to in degrees Celsius? (1400 °F = 760 °C)

So if we want an operating resistance of 4.47 Ω ...

$$4.47\Omega = R_0\left|1 + 4.0\times10^{-4}/^\circ C(760^\circ C - 20^\circ C\right|$$

...and the cold resistance of our wire should be 3.45 Ω.

What was the resistance of our wire? (should be around .0221Ω/cm)

At this rate, how much length do we need to get 3.45 Ohms? (156 cm)

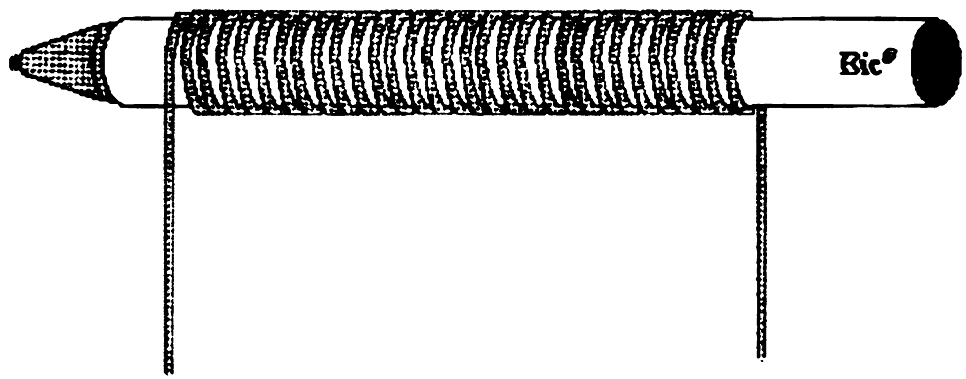
*Slightly more wire would be better than less because we can always get more power by shortening the coil therefore getting less resistance and more amps. Also you need about 2-3 cm on either side to attach your leads.

[Cut lengths of 160 cm for each lab group and show them how to coil around a Bic© pen. The coil should be tight but not touching itself. Wire to transformer w/electrical tape. Check each lab station, and then allow them to heat the coils up.]

[overhead]

APPENDIX V-B

Wrap coil of wire fairly tight around a pen Use #20 gauge Nichrome wire and a round pen. (Blue ink works best)



Students should probably wear goggles for this part. If they get overzealous with their wrapping, the long end of the wire is sharp and tends to whip around.

APPENDIX V-C

Consumer Electronics

Name ________________

1a. Just for old times' sake, use the value of a Watt to figure out how much power it takes for a 755 kg Porsche to go from zero to 26.7 m/s (60 mph) in 4.95 seconds. This is easier than you think. ________________

(Hint: What are the units for Watts, and $d = v_i t + \frac{1}{2}at^2$)

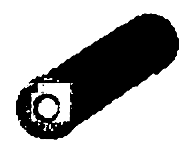
1b. If 746 Watts equals 1.0 horsepower, what is this equivalent to? ________________

2a. How does electricity get converted to heat in a toaster oven? ________________

2b. If a toaster is rated at 280 Watts, how much current is flowing through the heating element when it is plugged into the 120V outlet? ________________

3a. Why does a flashlight bulb light up immediately when the drift velocity of electrons through a DC circuit is less than a thousandth of a meter per second? ________________

3b. What is the net drift velocity of electrons in an AC circuit? ________________



3c. If a student claims that a battery works by providing charges that move through a wire creating current, what is wrong with this logic?

4. When a light bulb in a lamp is turned on, it gets hot enough to give off visible light, but the wires in the cord stay cool. What does this tell you about their relative resistances? ________________

5. What is the internal resistance of a 6.0 Amp vacuum cleaner when it is plugged into a 120V outlet? ________________

6. If the copper in a wire with a diameter of 10 millimeters were stretched into a wire with a diameter of 1 millimeter, the new wire would be 25 times longer. What would happen to the resistance? ________________

7. In Europe, electrical outlets work at a potential of 240 Volts whereas in the United States, they operate at 120 Volts. What would happen if your Uncle Sal from the old country plugged his European hairdryer into your bathroom wall?

APPENDIX VI-A

If You Can't Stand the Heat...

Now that we've figured out how we're going to heat our oven, how are we going to monitor the temperature so that we don't turn our cookies to hockey pucks?

-What are some of the ways we monitor temperature?

*thermometer, touch, color change... (write down)

*most thermometers work on expansion. (mercury, bimetallic strip)

Since we are going to be working at very high temperatures, we are going to build a device called a thermocouple. A thermocouple is a device that measures temperatures by gauging the change in potential created between two dissimilar metals.

-Thermocouples make use of a thermodynamic property called the **Seebeck effect**.

*The Seebeck effect was discovered by Thomas Seebeck, (1821) an Estonian Physician, who was studying the effect of heat on galvanic connections. He had joined Bismuth metal and Copper into a loop circuit and was heating it when he noticed that a nearby compass needle was deflected. He called this discovery thermomagnetism.

What he had discovered is the principle that all thermocouples work on:

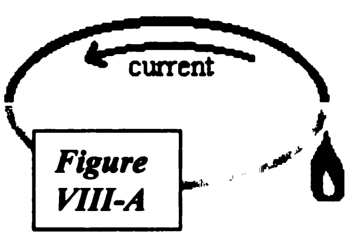


Figure VIII-A

Electric current flows through a closed circuit of two dissimilar metals when one of the junctures is heated with respect to the other. (draw)

-The greater the temperature difference between the hot juncture and the cold juncture, the greater the electric potential (Voltage) will be. If $\Delta T=0$, $V=0$

Naturally you are wondering, "Why does this happen?" Any ideas? I had a guy from the gas company come to my house once because the pilot light on my water heater kept going out, and he suggested that I change the thermocouple. He even told me how I could change it myself to save some money, which was good. It only cost me about $20 to fix, but being naturally curious I asked what the thermocouple was made of. He took this as me asking how a thermocouple works and proceeded to explain for 5 minutes how pressure builds up inside and triggers a cut-off, all the while I'm nodding my head and thinking, "This guy is off his gourd."

Anyways...for the real explanation, you have to go back to what you learned about electrons in Chemistry. What do you remember?

-You know that electrons orbit the nucleus of an atom,

*and that they do so at certain discreet distances or energy levels. (shells)

-You know that the inner energy levels fill up first.

*and that it is only the outermost electrons that take part in bonding, conduction...

(Now it gets a little funky here, but stick with it and stop me immediately if you have questions.)

Traditionally we labeled the different energy levels as 1s, 2s, 2p etc...(remember?)(draw) This is an assumption for a single atom with no outside influence. In a solid, (draw) however, each atom is surrounded, and the electrons of one atom influence the electrons of the others. Since electrons exhibit wave properties, each adjacent electron has to have a different energy (of its own), so the traditional 1s sublevel actually consists of several discreet levels that are referred to collectively as an energy band. The other occupied ground-state levels (2s, 2p etc..) also merge with the 1s into one big band called the valence band.

Figure VIII-B

For most substances, even the outermost electrons are pretty much bound to the nucleus, they are in lower energy orbits that fall within the valence band and, in order to escape they must absorb energy or jump to a higher energy level within the conduction band. In other words, they absorb enough energy that the nucleus can no longer hold them and they are "ionized".

-It is also true that for most substances the valence bands (energy levels) and the conduction bands are separated by a forbidden bandgap. This represents the minimum amount of energy that must be absorbed by an electron to be ionized. Electrons get this energy by absorbing it during collisions, so at any given instance, there are at least a few electrons in the conduction band.

*If the bandgap is big, the substance is an insulator.

*In metals, the bandgap is either small or nonexistent because the valence and conduction bands overlap. This makes them good conductors.

(If you remember from Chemistry and Physics we said that metal atoms exist as cations in a sea of their own valence electrons.) (draw)

Now where were we? If we consider two different elemental metals, (Iron and Copper) each has a different number of protons in the nucleus and a different number of electrons, so the energy level of the outermost valence electrons is not going to be the same.

It turns out that the outermost free electrons in Copper have less potential energy than those in Iron. (They are closer to the nucleus) This is because it takes less energy for a Copper atom to gain or lose an electron.

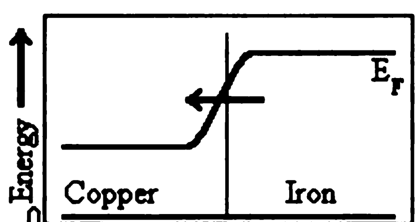


Figure VIII-C

Therefore, once you put the two metals together, there is an electric potential between the two. Since the **Fermi level** (The average of the highest occupied energy levels within an atom.) of the electrons in the Iron is higher, (the electrons need less energy to move within the Copper) they will move into the Copper and the moving electrons will make a current.

[Show thermocouple]

By now you must be saying to yourself, "But wait, what about the other juncture? If the current flows one way around the loop, won't the electrons be going against the electric field when they go from Copper to Iron." Yes, and all things being equal, they won't flow at all.

This is where the thermo- in thermodynamics comes into play. The current will only flow if there is a temperature difference between the two junctures. Since the electrons need more energy to move within the Iron, in order to get them across that boundary, they have to absorb energy from the surroundings.

An analogy can be made between the closed circuit of a thermocouple and a closed loop of glass tubing filled with water. **[overhead] [convection tube]**
-If the water is at equal temperature, the gravitational potential makes it want to flow down on both sides. What keeps it from doing that?
*This is analogous to the electrons wanting to leave the Iron, when they start to flow across the boundary, the Copper side quickly becomes more negative and prevents any more electrons from entering.

-In the case of our loop of glass tubing, if the heating coil is turned on, the water heats up, becomes less dense and rises.
*This is analogous to the heated juncture of the thermocouple providing the energy electrons needed to move against the electric potential.
**It is not really the heated side of a thermocouple that drives the current though, but rather electrons being "pulled" from the cold juncture side. If a juncture is heated the electrons still want to move "with" the potential.

-Let's suppose we were to turn the heating coil on and get the water flowing in one direction. What would happen when the heating coil was turned off?
What if there were no friction in the water?
*The current would still eventually stop, because it would be thermodynamically unfavorable for it to continue. Why? Well, let me ask you a question:
-What would happen to the water as it moves upward on one side of the tube?
-What would happen to the pressure on the water?
-What happens when pressure on a fluid is decreased? Increased?
*This would cause one side of the tube to heat up and the other side to cool down, which means a decrease in entropy (increase in order). (Doesn't happen in nature)

The same thing happens in a thermocouple. As electrons go from high potential to low potential, they give off the excess energy as heat in collisions.
(Draw an electron going from high orbit to low)
The electrons on the heated side move towards the cold side trying to distribute the heat evenly. (Electron "pressure" is created because faster moving electrons repel more.)
As long as you keep pulling away the heat from the cold juncture, the current flow continue.

The greater the temperature difference between hot and cold becomes, the greater the potential (voltage) becomes because the Fermi-level mismatch becomes more exagerated.

This is why thermocouples are used to power sensor equipment left on the moon. The difference between the shadow side vs. the sunny side is great enough to charge batteries.
[reversible thermoelectric demonstration device]

If we go back to our analogy of a loop of water, what would happen if the current were forced in one direction? At one juncture→ electrons would go from a material with a higher Fermi level to one with a lower Fermi level. Their excess energy would be given off as heat.

At the other juncture, electrons would be forced to go from lower energy orbits to a higher energy orbits. Since only the hottest or most energetic electrons would cross the boundary, the average energy of the ones left behind would be lower, hence that juncture would cool.

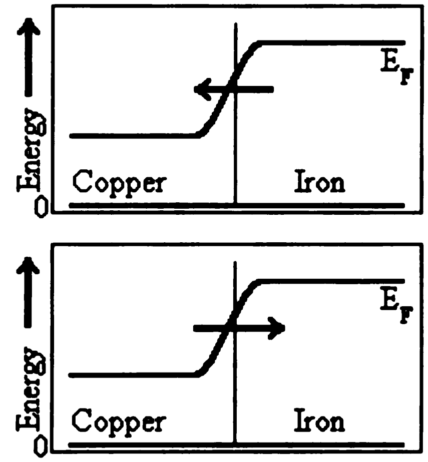


Figure VIII-D

This is known as the Peltier effect. (Jean Peltier, 1834)
[reversible thermoelectric demonstration device]

The Peltier effect can also be seen in those fancy new coolers you can buy at Cabela's

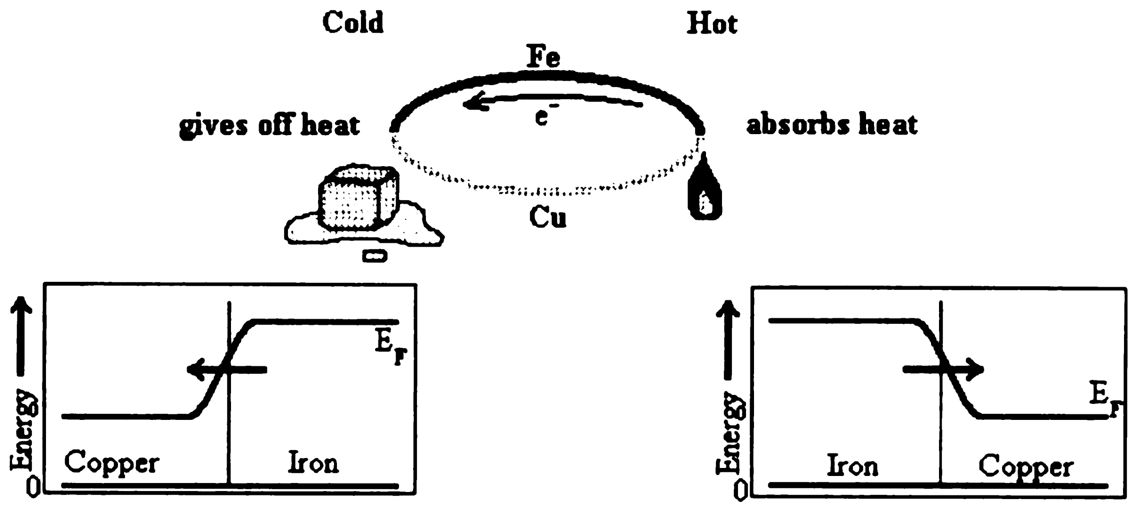
In Physics, how do we measure electron pressure or electric potential? (Volts)
At a thermocouple juncture, as the temperature rises, the Fermi level difference between the two materials gets larger, and so there is a greater difference in the potential energy that electrons have on either side of the boundary. This difference in potential energy is measured in Volts and can be calculated using **<u>Seebeck coefficients</u>** (A measure of the average potential energy of electrons within a material. according to the equation:

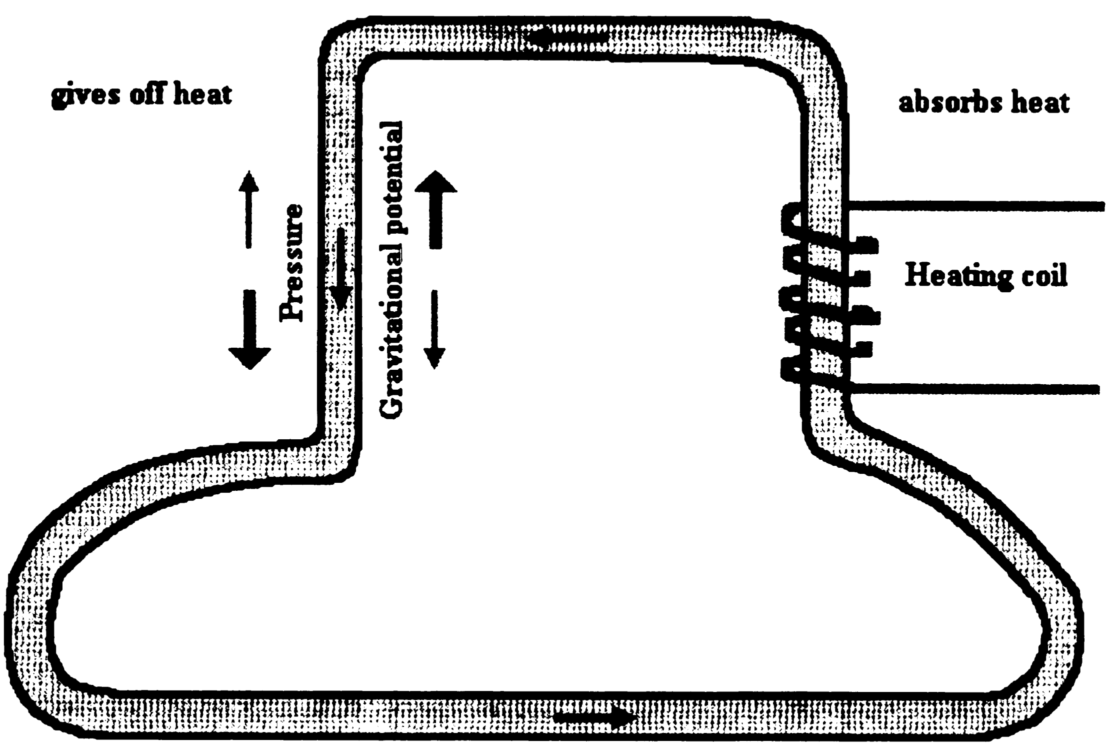
$$\Delta V = (|S_A - S_B|)\Delta T$$

Where the S variables represent the Seebeck coefficients for the two materials (measured in microvolts per degree Kelvin) and ΔT represents the temperature difference between the two junctures in degrees Kelvin. **[overhead]**

Once we build our own thermocouples we can verify this equation and the values on the chart.

APPENDIX VI-B





APPENDIX VI-C

Seebeck Coefficients (μV/°C)			
Material	Coefficient	Material	Coefficient
Aluminum	3.5	Rhodium	6.0
Gold	6.5	Antimony	47
Silver	6.5	Iron	19
Copper	6.5	Selenium	900
Bismuth	-72	Lead	4.0
Cadmium	7.5	Silicon	440
Mercury	.60	Carbon	3.0
Nichrome	25	Sodium	-2.5
Constantan	-35	Nickel	-15
Tantalum	4.5	Tellurium	500
Germanium	300	Potassium	-9.0
Tungsten	7.5	Platinum	0

APPENDIX VII

Fight the Power!

(Join up with the Resistance)

Name ________________

A. Truthful/Fraudulent:

_____ 1. On a multimeter, battery, or power supply, conventional current moves from the red terminal (+) to the black (-), while electrons move in the opposite direction.

_____ 2. Wiring two batteries in series (The positive terminal on one connected to the negative terminal on the other.) will double the voltage.

_____ 3. The power lost due to joule heating in a wire is equal to IR^2.

_____ 4. The resistance within a wire increases as the wire gets colder and the atoms begin to move slower.

_____ 5. A toaster wire gets hot because it has an extremely low resistance compared to the lead wires to which it is connected.

B. More Good Stuff:

6. Name three of the many factors determining the resistance that a particular wire will have. Be specific.

____

____

____

7. What happens to the resistance in a wire if the diameter of the wire is tripled? ____

8. What is the power delivered by a wire with a potential of 12.0V and a resistance of 2.44Ω? Show both formulas.

Extra Credit: What are the units on resistivity?

APPENDIX VIII

Physics Even a Biology Major Could Love

Name ____________________

Introduction:

Thermocouples are the most widely used devices for measuring temperature today. This is because they not only cover a much larger range than other thermometric devices, but they can be made to be almost indestructible. In this lab you will build and calibrate a type "T" thermocouple for use in your Sneezy-Bake Oven.

Materials:

1 cm Tin/Silver solder	soldering iron	soldering flux
ringstand	ringstand clamp	wire screen
250-mL beaker	400-mL beaker	Bunsen burner
2 Dart® foam cups	alcohol thermometer	6V lantern battery
(one 8J8 and one 12J12)	tweezers or tongs	wire strippers
masking tape	multi-meter	ice
#28 gauge Constantan wire	#22 gauge Copper wire (coated)	

Procedure: (Day one)

1. Plug in your soldering iron and rest it on a ringstand so that the hot tip stays away from the lab table surface. With the wire strippers, remove approximately 3 cm of the insulation from one of the ends on each of your two pieces of Copper wire and 12 cm from the other end. Also remove 12 cm of insulation from both ends of the Constantan.

2. Fill a large foam cup with ice cubes and add water until it is almost full. Use a smaller cup as a top to keep the ice-water bath insulated. With a pencil make a small hole in the bottom of the small cup so that you can insert one of the soldered junctures.

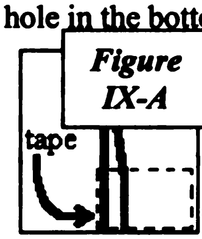


Figure IX-A

3. Hold one of the Copper wires by the end from which you removed more of the insulation and place one end of the Constantan right next to it so that the tips of both wires are even. (See diagram) Use a small piece of masking tape to hold them in place. Once they are taped, dip the wire ends about 5 mm into some solder flux. All you need is a tiny amount to help the solder bond with the metal. Prepare the other end of the Constantan wire in a similar fashion with your other Copper wire.

4. Using your tweezers or crucible tongs, hold a small piece of solder against the tip of the soldering iron until a bead of melted solder is deposited. Holding one of the junctures by the flap of tape, touch the bare wire ends to the bead of solder and quickly remove them. It may take some practice, but you want just a small bead of solder connecting the wires. (See diagram) Once the solder has cooled, remove the tape. Do the same with the other juncture. Wrap a small section of tape around the two wires about 10 cm from the solder to keep them from pulling apart. Since the bead of solder is so small, it tends to come apart if you are not careful.

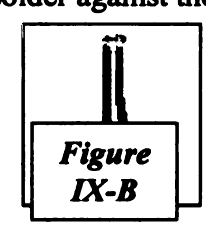
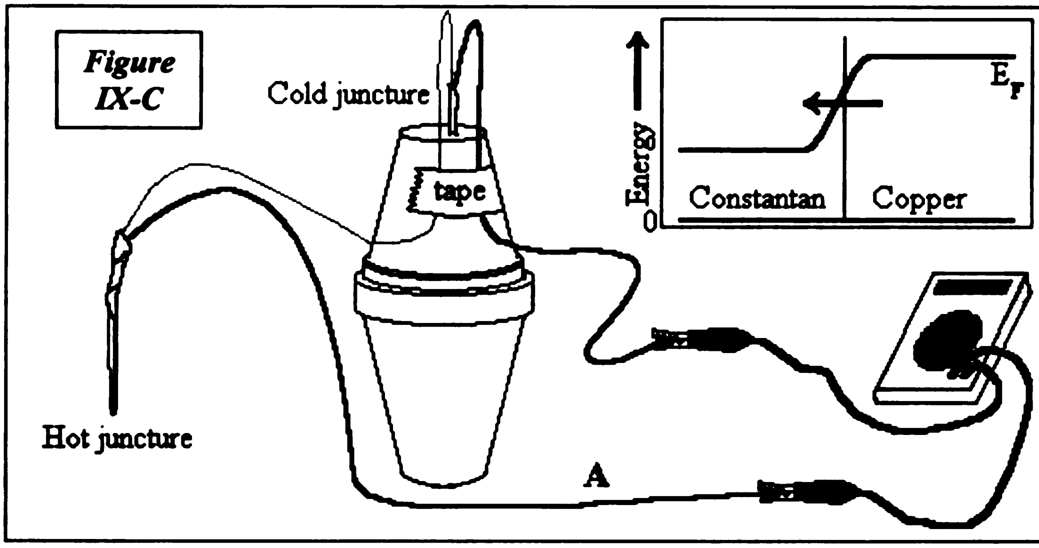


Figure IX-B

5. When you have completed both junctures, insert one into the hole in the small Styrofoam cup so that the tip extends at least 6 cm into the ice water. Tape the wires to the outside of the cup, and hook them to the voltmeter as shown on the next page.



Now that you've built your thermocouple, turn the voltmeter on and set the dial to the smallest DC voltage position. Once you get a steady reading, gently hold the hot juncture between your fingertips and note the change in voltage.

Based on the fact that the Fermi energy in the Constantan is lower than that in the Copper, what direction will the electrons at point A flow? ______________________ Conventional current traditionally is opposite of the direction that the electrons are travelling in. (Don't ask me why they haven't changed it yet.) The black receptacle on the voltmeter is the one the electrons are supposed to flow out of. If you hook your circuit up so that they flow that way, you will get a positive voltage.

6. Pull the smaller cup out of the ice-water cup and very gently dry off the cold juncture. Hook up a 6V lantern battery in place of the voltmeter, so that the former cold juncture lead is attached to the negative terminal and the former hot junction lead is attached to the positive terminal. (Just think of the terminals of the battery as train terminals and remember; red or positive means incoming electrons, negative means outgoing electrons.) Wired in this way, the battery will force the current to flow in the same direction that it was travelling before.

Looking at the schematic in the upper right corner of the diagram, consider the juncture where the electrons are flowing from Copper and into the Constantan wire. Would you expect this juncture to heat up or cool down? Explain your reasoning.

____

____

____

____

With your fingertips, very lightly pinch each juncture at the same time. Were you right? This phenomenon is known as the Peltier effect as French physicist Jean Peltier discovered it in 1834. Today, this fact is put to use as a way to cool the insides of computers. You may have also experienced the Peltier effect in use if you own one of those new picnic coolers that either warm or cool your food depending on what setting you turn it to. Peltier heaters and coolers are seeing ever increasing use as the technology improves because, unlike traditional methods of heating and cooling, they are perfectly quiet and they don't require ozone depleting gases or produce harmful by-products.

Procedure: (Day Two)

Today you are going to calibrate your thermocouple by comparing it to values obtained from a typical alcohol thermometer and extrapolating a line into the region of normal cooking temperatures.

1. Set up your Bunsen burner and ringstand so that you can heat around 300 mL of tap water in a 400-mL beaker. While this is heating, add ice cubes and water to the cold juncture bath and set up your thermocouple. Also add water and ice to a 250-mL beaker. Let the ice water in the beaker set for a few minutes to get cold and then remove all the unmelted ice.

2. Place the alcohol thermometer into the cold water in the 250-mL beaker and hold it at least a few centimeters from the bottom. Place the "hot" juncture of your thermocouple into the water so that the tip is close to the bulb of the thermometer and wait a minute for the temperature to equalize. There should be at least 6 cm of the thermocouple wire immersed in the water. Record the values for both instruments to the limit of their accuracy.

3. Add small amounts of hot tap water to the cold water in the beaker, wait, and take measurements every 3-4°C until you get to about 35°C. Once the tap water in the 400-mL beaker starts to boil, have your instructor remove the beaker from the ringstand. Starting at around 95°C, add cool tap water and take measurements in a similar manner until you reach about 40°C. Convert each of the Celsius measurements to Fahrenheit.

Voltage (mV)	°C	°F		Voltage (mV)	°C	°F

4. On the graph provided, make a plot of Temperature vs. Electric Potential. Along the vertical axis, label the temperature in Fahrenheit from 0 to 400 degrees, and label the electric potential along the bottom from 0 to 8 milliVolts. Plot your values and make a line of best fit through the data points.

Why would you expect the y-intercept value to be 0 milliVolts?__________________

____

____

When we use the values of the line you've create to approximate the temperature inside your Sneezy-Bake Oven, what sources of error should we try to look out for?

____

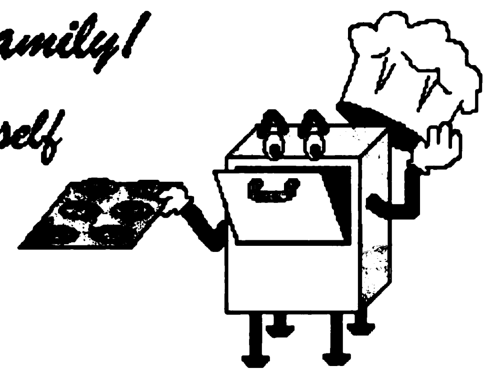
APPENDIX IX

Amaze and Delight

your friends and family!

With treats you make yourself

Just like Mom!



Care and Use of Your Sneezy-Bake Oven®

Product #110-6647

PLEASE READ INSTRUCTIONS CAREFULLY

Thank you for choosing to purchase a Sneezy-Bake Oven® for your child. In order to ensure hours of baking fun, please read all instructions carefully. A grown-up should assist in the assembly and be present whenever the oven is in use.

For more role-playing fun try our newest product "Doggy Dentist".

**This is an electric toy. Conglomerated Industries and its subsidiaries are not responsible for injuries due to burns, electrocution, or fires caused by this product.

Materials:

Kleenex® box	Swingline stapler	Heavy duty Aluminum foil
Craft knife	Paper punch	4-3½"×¼" bolts
8-¼" washers	8-¼" nuts	Electrical tape
Scissors and ruler	Disposable cookie sheet	Paper fastener
2-2' sections of lead wire	Heating coil	Thermocouple

Procedure:

1. Carefully open one side of the Kleenex box without ripping the cardboard flaps and remove all the plastic and glue from around the opening in the top. Henceforth, the top will be known as the bottom, and the side that you opened will be the left side, with the oven door opening going in front.

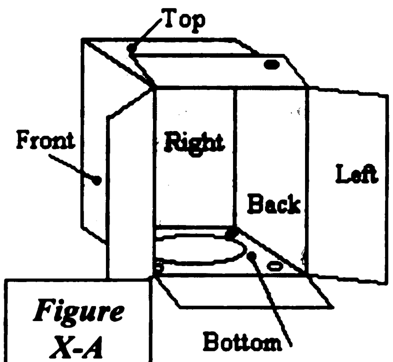


Figure X-A

2. Using a paper punch, make four even holes around the oval opening in the bottom (see diagram) as far in towards the corners as possible. Try to avoid stapling over these in the future.

3. Cut a piece of heavy duty Aluminum foil into a rectangle that measures 4½" by 18". Lay the piece flat and, with a pen and ruler, draw lines straight across at 6⅜" from both ends. With scissors in hand, cut ¼" into the rectangle where the lines meet the edges. This piece is to cover the inside of the top, right, and bottom panels. Make sure that the shiny side faces in and then carefully staple the foil in place. Put two staples in front and two in back on both the top and bottom panels. Stapling towards the back (right panel) will be easier if you fold the flaps of the left panel back first. You will have some foil extending outside the box. Fold the excess around the top and bottom flaps of the left panel. Clear as mud? Good.

4. Fold the top flap of the left panel back over the top panel and use a paper punch to make a hole in the through both layers of cardboard and Aluminum foil. (as shown in the diagram) This will leave a hole in the flap, but it will be covered. The hole in the top is where you will insert the hot juncture of your thermocouple.

5. Lay the box on the lab table with the front panel facing up. With a ruler and pen, make a neat square on the front panel that measures 1" from the top, 1¾" from the bottom and ¼" from the left and right sides. This will be the opening to your oven. With a craft knife, score the top, left, and right lines of the square you've just made. Don't cut all the way through just yet. This will make the cutting process easier. Now push the blade of the craft knife all the way through one of those lines and use it to gently "saw" through the cardboard. Don't cut the bottom line or you will have a hole rather than a door. Use a ruler to neatly bend the door outwards.

6. Next cut two rectangles of Aluminum foil that measure 7¼" by 8". For each, measure in 1" from three of the sides and 2¾" from the other and make lines as shown in the diagram. Cut out the corners and use these to cover the inside of the front and back panels. The longer flaps of foil should point out to that they cover the side flaps on

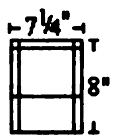


Figure X-B

the left panel. Staple these to the front and back panels first. Be sure not to staple through your oven door.

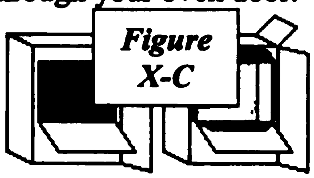


Figure X-C

7. Open the oven door and use a craft knife to cut the Aluminum foil on diagonal lines as shown in the diagram. Fold the flaps outward and secure them with staples. Cut a 5" by 3" piece of Aluminum foil  and use it to cover the inside of the oven door. You can even add a handle to your door by adding a paper fastener or a tiny bolt with two nuts.

8. Use the long bolts as legs for your oven by inserting them through the holes in the bottom panel. (Be sure not to tear your foil) Secure the bolts in place by sandwiching the cardboard between two washers and tightening the nuts around them.

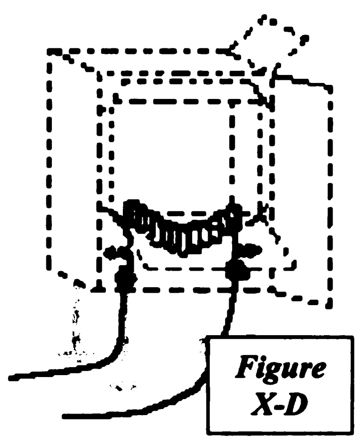


Figure X-D

9. Next, make two small holes in the bottom panel with a craft knife; one on the left and one on the right of the oval opening. These will be where you will insert the leads for your heating coil. Use two 2' sections of coated #22 gauge Copper wire. Remove a few centimeters of the insulation from each end, and on one end of each wire, make a small knot close to the exposed end. Connect the knotted ends to your heating coil and feed the other ends through the small holes in the bottom so that the knots rest there, but none of the exposed wire is touching the foil. This may take a bit of finagling. Once you have accomplished this, close the flaps on the left panel and carefully staple them in place.

10. Cut a 16" by 8" piece of Aluminum foil and fold it hamburger style twice so that you end up with a thick piece measuring 4" by 8". Measure in 2" on either end and make a line. Use a paper punch to thoroughly perforate this piece of foil between the two lines. This will be your cooking rack. Staple your cooking rack into your oven so that it is suspended like a "U" and is even with the bottom of the oven door. Be careful when you staple so that to don't rip the ¼" border on either side of the door. It is very important that your cooking rack be level or your cookies will slide as they cook.

11. Cut a 4" by 4" square of Aluminum from a disposable cookie sheet and draw a square in the center (use a pen) with a ¼" border on each side. Cut out the corners and roll the edges towards the center to make a 3½" by 3½" cookie sheet. After that cut a 3" by 3" square of corrugated Aluminum and cover it with aluminum foil to form a baking pad. This will help keep your cookies from burning on the bottom.

12. You are now ready to go. Insert your thermocouple junction into the hole at the top so that at least 6 cm is within the oven and tape over the hole. If needed, bend the thermocouple wire so that it is about 2-3 cm from the top of the oven and at least 4-5 cm away from the oven door. Fill the ice water bath and connect the wires to the multimeter.

13. Connect the leads of the heating coil to the transformer (MAKING SURE IT IS NOT PLUGGED IN AT THE TIME) and cover the exposed wire with electrical tape. Make one last check of the heating coil to make sure it is positioned right and is not touching the Aluminum foil. Once you are ready have your instructor give you the O.K. and plug in your new SneezyBake Oven. Using your calibration graph, let the oven heat for about ten minutes to see where the temperature tops out. If at any time you see sparks

or smoke, or should the temperature rise above 400°F, unplug the transformer and call your instructor. Adjustments may have to be made, but you should now be ready to bake.

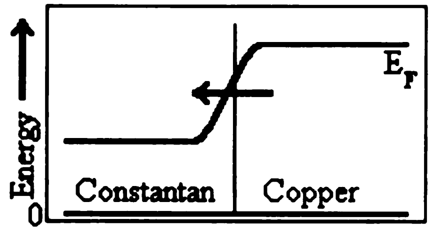


Figure X-E

1a. Draw a simplistic diagram of your Sneezy-Bake Oven set-up and use arrows to show the direction the electrons travel through your thermocouple. Be sure to label which plug is positive and which is negative on your multi-meter.

1b. Based on the diagram, which substance has a higher Fermi level? ____________

2. Why is it important that the exposed part of the thermocouple juncture not touch the sides of the box? ____________

3. What is the purpose of using a transformer in this lab? ____________

4. Why doesn't it matter which of the black transformer leads are connected to the left side (side with the fatter prong) of the extension cord? ____________

5. Explain why the plastic on the wires going from the transformer to the heating coil don't melt, when the same amount of current flows through all three. (Please do not say, "because they don't get hot enough.") ____________

6. If your heating coil has a resistance of 4.98 Ohms when the transformer is supplying 18.75 Volts, how much heat is dissipated by the wire?

APPENDIX X

Termiknowlogy

Name___________________

a. Joule heating	b. resistance	c. negative
d. Seebeck effect	e. series	f. thermocouple
g. whiz	h. multimeter	i. transformer
j. resistivity	k. power	l. forbidden gap
m. Peltier effect	n. conduction band	o. voltage
p. valence band	q. current	r. Fermi level
s. positive	t. activation energy	u. parallet

1. The coil on a hot plate warms up as current flows through it in a process known as _____.
2. Most people know that a positive terminal is typically red and a negative terminal is black. When wired in a circuit, electrons (not conventional current) flow out of the _____ terminal.
3. If the energy an electron gains exceeds the activation or ionization energy it jumps into the _____.
4. & 5. A _____ is created when one juncture in a simple closed circuit of two dissimilar metals are heated with respect to the other. This is a demonstration of the _____.
6. When comparing wires of the same length, made of the same material and at the same temperature, a wire that has twice the diameter of another will have a _____ that is ¼ as much.
7. Wiring two batteries in series will result in a larger _____ in the circuit.
8. The _____ represents a range of energies (or possible distances from the nucleus) that an electron can have and still be in a stable orbit.
9. The_____ of a material does not depend upon length or cross-sectional and is proportion to the square root of the Kelvin temperature.
10. At a juncture between two dissimilar metals the tendency of electrons is to flow from a higher to a lower _____.

Extra credit: In the equation for finding the thermal velocity of an electron:

$\frac{1}{2} mV_T^2 = KT$ what does K stand for? _____

APPENDIX XI

Word Processing 1.0

Ever since the development of data, (mankind) men have sought better ways to sort, arrange, manipulate, and store it. In fact the oldest example of Sanskrit (the first known form of writing) is a clay tablet that was a record to keep track of farm goods.

Most of the hieroglyphics (that are the most well known early writings) are not exciting pharaoh gossip, but are accounts of weather, harvest totals, and records of armies. **[picture]**

It seems that keeping track of data may have led to written language. This is due in part to the fact that counting has always been very important. Good accounting makes the difference between staying in business and bankruptcy.

The word calculus comes from the counting of pebbles—(Roman chariot taxis)
The abacus was developed 1,500 years ago in the Mediterranean—Still used by the Chinese today. **[picture]**

For a thousand years there were no advances in counting machines until Blaise Pascal (heard of?)—French, son of tax official; father had the tiresome job of adding up the tax rolls. Pascal develops machine to make his life easier. **[picture]** —Used cogs & wheels (slow)

Leibniz (German) made the next advance in Counting Machines when he improved on Pascal's design and made a machine, which you punched numbers into and then cranked. This made it possible to multiply and divide. (Explain) 3x4 = 3+3+3+3 (limited with big numbers)

Charles Babbage (?) designed a machine, which he called his "great analytical engine" which with one crank could multiply or divide large numbers. It had countless cogs and wheels and he never got it to work before he passed away. A few years later, a Swedish company built it and made it work. **[picture]**

The next step in counting machines began with the making of fabric. Anyone ever heard of a Jacquard sweater? Gets its name from the Jacquard loom. **[picture]**
(Draw loom)-Explain how it ties thousands of knots/min, punched leather belt (kind of like a player piano) --In a sense this was "programming."

Herman Hollerith used this same method on his tabulating machine. (Used punch cards). Used it to tabulate and analyze the 1890's census (people were mailed cards). By inputting weather data,

Hollerith hoped to predict the weather. Five years before his death, he created a company that made adding machines. (cash registers-IBM)

THE BEGINNING OF THE COMPUTER AGE

The next major step after cash registers was to add electricity. 1939 – gearing up for World War II—Navy needed trajectory (ballistic charts for big guns) –Charts factored in humidity, air pressure, Coriolis effect, distance, elevation… --Took hours to calculate even a few of the numbers,-- Very complex formulas with big numbers—No calculators at this time. All by hand.

The Navy wanted a machine that could process large numbers fast, so they built the Mark I (8 ft. high, 51 ft. long) --Used electronic switches instead of gears. **[Draw picture]** We will talk about switches later. Around 1941 once the war started, and the army wanted a machine to help solve the problem of cracking German codes. (They used complex formulas called algorithms).

Called the ENIAC- (Electronic Numerical Integrator And Computer) – Now called computers (18 ft high, 81 ft. long) **[picture]** To program it, you had to plug and unplug wires. **At the time it was thought that the world would never need more than 6 to solve all of its mathematical problems (Anyone have a calculator?)

(Used 18,000 CRT's – more air conditioning equipment than the Empire State Building) ENIAC used cathode ray tubes instead of electronic switches—Kind of like light bulb – get hot, burn out, moth problem – "debugging" **[Draw picture]**

The first Cathode Ray tubes were diodes. A diode is an electrical device that only allows current to flow in one direction.—Invented in 1904 by Brit John Ambrose Fleming **[Draw picture]** - Electrons would only flow one way (how would this be useful?)

Two years later, American scientist Lee de Forest invented the triode (essentially an on/off switch). **[picture]** – The advantage of this device is that it can be used to amplify a weak electric signal (such as the signal a radio-wave induces in an antennae).The disadvantages of the triode were that they were bulky, took a lot of electricity, and they burned out.

The development of a solid-state transistor by Shockley Bardeen and Brattain, in 1948, changed the world and ushered in the Information Age.

APPENDIX XII-A

Solid-State Physics

The development of the computer chip and the components that preceded them all hinge on the properties of a special class of materials called semiconductors. For metals, the number of valence electrons does not determine crystalline structure because these electrons are free to move. In a substance like diamond, they are not free to move because it is a nonmetal, and they (the electrons) are held more tightly.

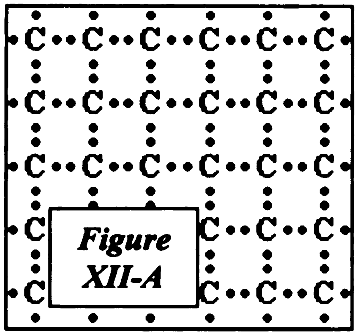


Figure XII-A

If you look at the Lewis dot structure of carbon **[draw picture]**, you can see why it forms 4 bonds. For simplicity's sake you could draw diamond's structure as ←

The semiconductor silicon has the same electron configuration, but is a moderately better conductor because the outer electrons are further from the nucleus. The conductivity can be greatly improved by "doping" the silicon with impurities such as Gallium or Phophorus.

A silicon ingot is purified by slowly passing it through a heating coil. The impurities stay in the mobile liquid phase so that fewer than 1-2 parts per billion of impurities remain in the solid. **[picture]**

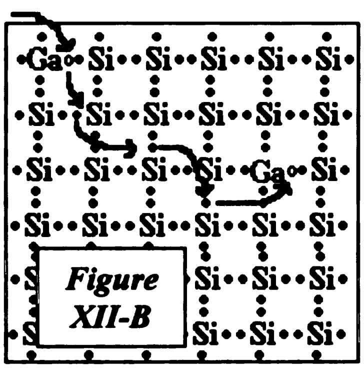


Figure XII-B

Thin wafers **[picture]** of this material are then exposed to vaporized metal "**<u>doping agents</u>**". If an element like Gallium is used, it replaces the occasional silicon atom creating holes because Gallium only has 3 valence electrons. **[overhead]**

–Since electrons shift to fill the hole, the "hole" moves when a current is applied.

This type of semi-conductor is called a **<u>p-type conductor.</u>**

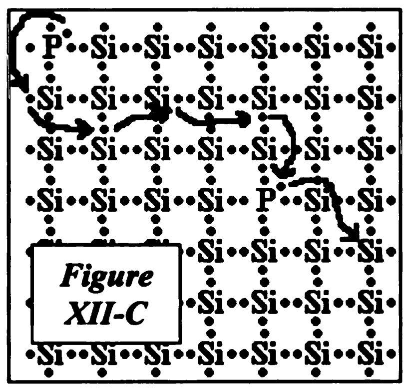


Figure XII-C

If Phosphorus is used as the doping agent, it forms an **<u>n-type conductor</u>** because Phosphorus has 5 valence electrons. →

If two layers (a "p" and "n") are placed together (with no electric field) extra electrons from the n-layer near the boundary flow into the holes in the p-layer and a zone of depletion forms. **[overhead]** This is a **diode**.

If electrons (draw) are added to the left side, they make the **zone of depletion** large and, since there are no free holes or extra electrons, it acts as an insulator.

If electrons (current) are added to the right side, they repel the extra electrons and attract the "holes" making the zone of depletion disappear, allowing the current to flow.

This means that the current can only flow in one direction.

-What could they be used for? (Diodes can be used as **rectifiers**.)

Light emitting diodes (LED's) emit light if doped with Ga, Al, As, or P. (How?)

Diode Lasers (draw picture- LED crystals)

Photo voltaic cells make use of a similar effect called the **photo electric effect**. This phenomenon was explained by Einstein in 1905. **[Draw picture]**

[Diagrams of...]

--Solar cells

--Photocopiers

-- remote control

--burglar alarms

--light sensor cameras

--bar-code scanners

By placing 3 layers in a sandwich you can make a **transistor**. **[overhead]**

If a small voltage is applied, it allows the large current to flow. If the small voltage is turned off, this shuts off the switch. Stereo amplifiers and computer chips are two examples of transistors in use. Information on a computer is stored as millions of these switches in either an on or off position. **(Show Transistors)**

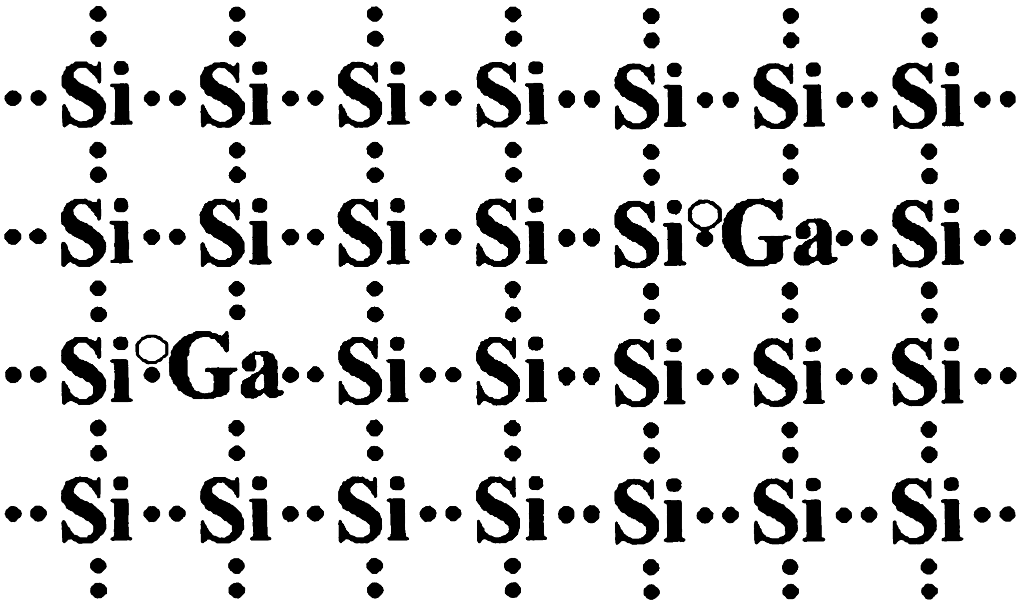
--[Transistor demo]

--[Amplifier demo]

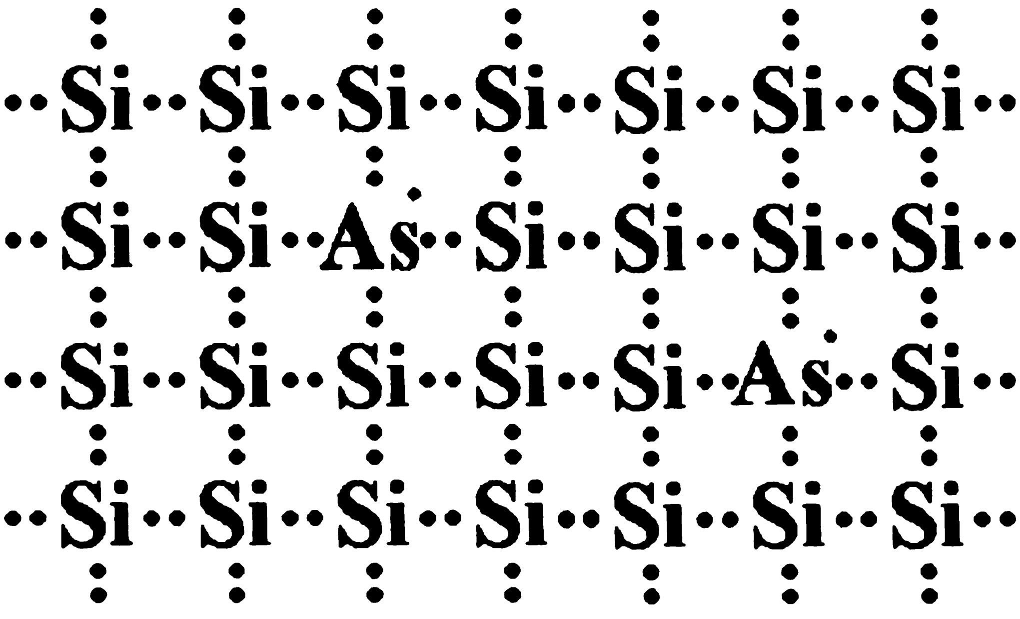
--[metal detector]

--(Switchboard story –amplified telephone signals because voltage created was weak, and as the wires became longer and ________ grew larger, making the signal weaker.)

APPENDIX XII-B

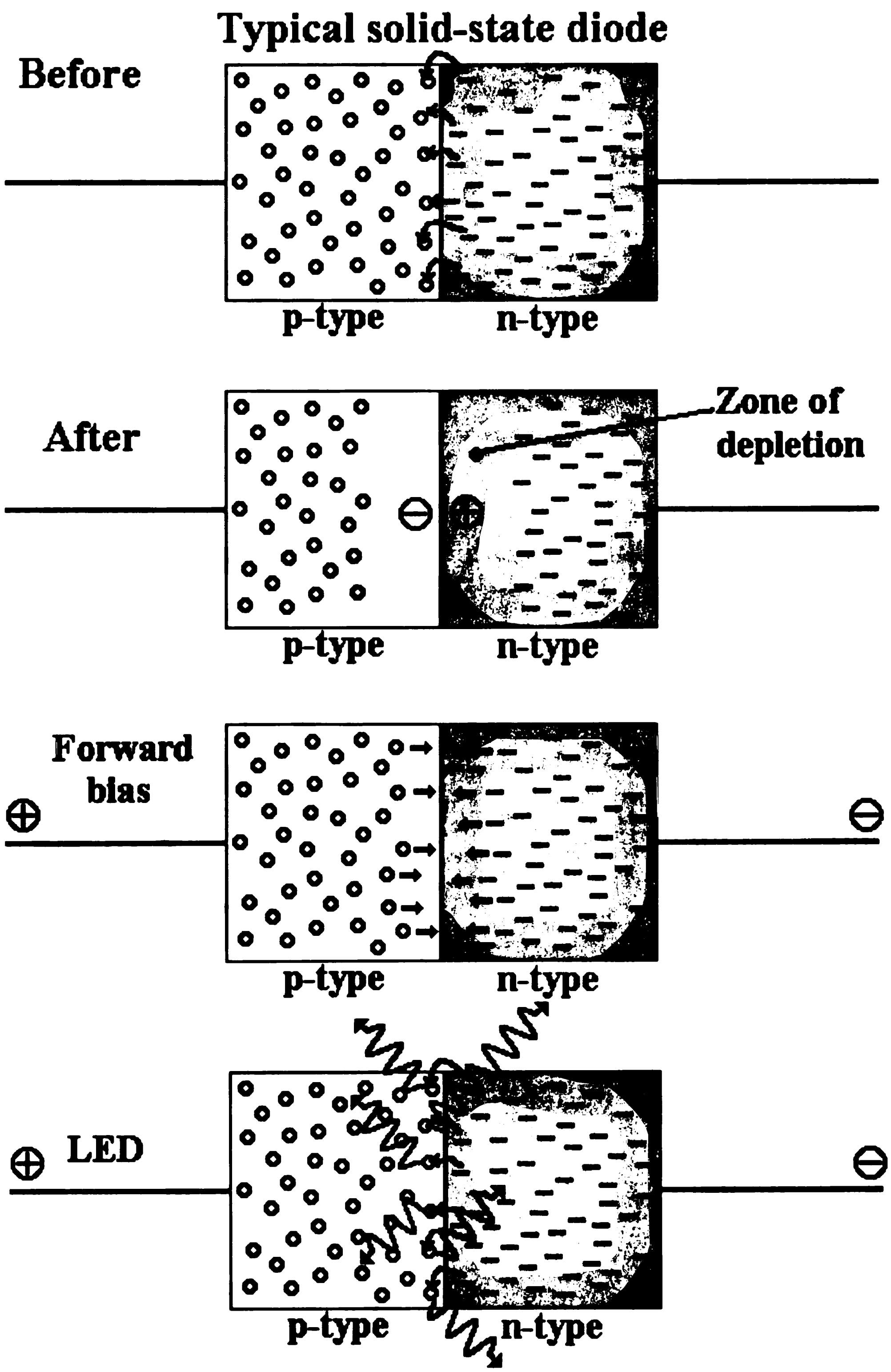


p-type



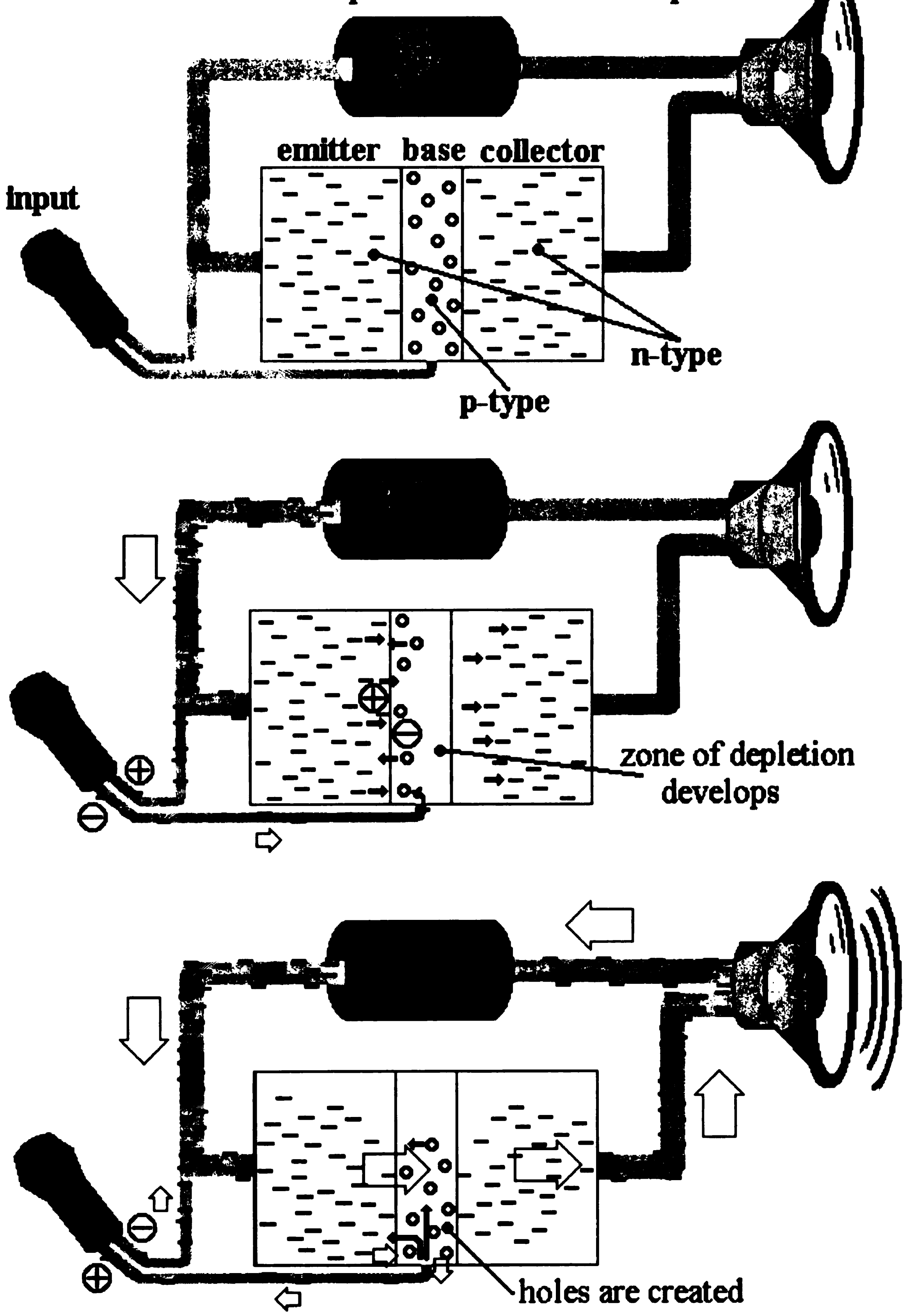
n-type

APPENDIX XII-C



APPENDIX XII-D

The basic set-up of a transistor amplifier

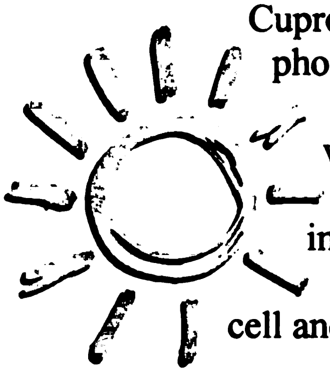


APPENDIX XIII

Solar Power

Name ________________

Introduction:



Cuprous oxide was the first material known to exhibit photovoltaic properties. This phenomenon became the study of a young German scientist named Albert Einstein who, in 1905, wrote a paper that both explained the photoelectric effect and marked the start of a journey into Quantum Physics that would earn him the Nobel Prize. In this lab you will build your own photovoltaic cell and use it to power a cheap calculator.

Equipment:

A 400 mL beaker, a 4×3 inch piece of copper foil, a small block of wood, a 4×2 inch piece of copper foil, a Bunsen burner, a pair of crucible tongs, an acid bath, a multimeter, two alligator clips, and a cheap calculator.

Procedure:

1. Obtain the two necessary sheets of copper foil and press them flat. Using your crucible tongs dip both ends of each sheet into an acid bath to clean the surface of any corrosion. Rinse both in water to remove the excess acid and blot dry with paper towel. Try to avoid touching the copper with your bare hands as this will deposit oils from your skin.

2. Light your Bunsen burner and with the crucible tongs hold the larger piece of copper horizontally above the hottest part of the flame until it glows orange hot for more than two minutes. Always keep the same side pointed away from the flame. Observe the pattern of colors that appears before the foil turns black. These are caused by partial oxidation of the surface. Very slowly lift the foil out of the flame keeping the same side pointed up. (Count to sixty and then lift the foil no more than one inch, and repeat until the foil is about six inches above the tip of the flame.) The smooth black coating of Cupric oxide should begin to blister and flake. Quickly remove the foil and set it on top of the wood block to continue cooling. The black coating (CuO) should start peeling up revealing a red Cuprous oxide (Cu_2O) coating underneath.

3. When the foil is cool, rinse it under tap water and **<u>very lightly</u>** brush with your finger to remove the remaining black. Blot with paper towel and allow it to air dry.

4. Fill your 400 mL beaker with about 300 mL of hot tap water and add a few tablespoons of salt while stirring. Connect the smaller piece of copper to the red terminal on your voltmeter, and turn the meter to the smallest DC Volt setting. Clip the foil to the side of your beaker that has the writing on it making sure that the lead does not get wet. Connect the black lead to the treated foil and clip it to the clear side of the beaker. Mr. Tuckey will bring around a large 250W lightbulb to simulate sunlight conditions.

1. Observe what happens to the multimeter reading when you place your hand over the outside of the beaker and then record the approximate voltage when the Cuprous oxide coating is bathed in light. ____________
2. Move the red clip to the milliAmp post and turn the dial to the lowest current setting. Record the current when lit. ____________
3. What is the approximate power supplied by your solar cell?

____

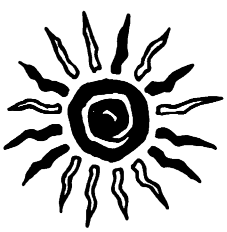
4. Why do you suppose the Cuprous oxide coating forms beneath the black Cupric oxide? ____

____

5. Based on the fact that the clean copper foil is connected to the red terminal on the multimeter, are electrons flowing out of or into the Cuprous oxide surface? ____________________
6. How would you explain what is happening if when a red filter is placed over all light sources in the room, the voltage reading drops to virtually nothing, yet if a blue filter is used, the voltage remains high?

____

____



7. Name three common devices that make use of the photoelectric effect.

____

____

____

If available, remove the battery out a small calculator and connect the positive and negative terminals to your photovoltaic cell. If there is enough power to operate the calculator, use it to solve the following problem:

8. If a homemade solar cell that measures 3 inches by 4 inches supplies a potential of .856 mV and a current of .488 mA, what surface area would be needed to power your Sneezy-Bake Oven that uses 3.59 Amps at 19.5 Volts?

APPENDIX XIV

"Necessity is the Mother of Invention"

Name ___________________

Yes, it is time once again to begin thinking about what kind of horrendous torture Mr. Tuckey has in store for us in the form of a Marking Period Project! Now before you start complaining (yeah, right.) bear in mind that this could be the second to last one you ever have to do. For this project, you will find it necessary to build a homemade version (or working model) of an electrical appliance or toy. You could choose from a list of projects I have already approved, or you could come up with your own idea. Once you have built this project, you will be required to give a verbal presentation of your particular gadget teaching us not only about how it works, but also about its history and cultural significance.

There are of course a few stipulations...

-All ideas must be approved by Mr. Tuckey. (By deadline)

-No pre-designed kits will even be considered. All construction should be done with materials that are readily available and cheap. (Parts can often be salvaged off junked machinery.)

-No Mickey Mouse, 2 minute ideas. When presenting your project, try to give us the complete story on your gadget. Be creative.

-Use of fire and chemicals is somewhat limited.

-As soon as the date is set for presentations, let Mr. Tuckey know if you have prior commitments or if you are a tech-center student.

-The science is the most important aspect. If it doesn't demonstrate some innovative thought or engineering, your idea will not be approved.

You are by now wondering how it will be graded...

This is the beauty part. You will be graded on three separate criteria by your fellow classmates; how well your gadget works, how much work you put into your gadget, and how much work you put into your presentation.

Just a few suggestions...

If you are looking for ideas, I have a list of ten possibilities. However, I am not going to reveal them until next week because I would prefer if you used your creativity and came up with an idea on your own. For this reason we will be going to the media center to research, but before we go I want you to sit still, be quiet, and brainstorm for five minutes. (This is not a joke.)

APPENDIX XV

Generation 01011000

Let me ask you a question. Your generation is known as the computer generation because ever since you were born, computers have been a part of everyday life. What is a computer?
It's probably hard for you to imagine life without them because nowadays they are found everywhere. Even your coffeepot has a computer in it. This is part of the reason why if it breaks; it's cheaper to buy a new one than to get it fixed.
--There is a huge shortage of people with the technical know-how to fix things today. There are so many computers within a newer car, that a good mechanic's garage has more technology than NASA had when they went to the moon.

This is something scary. Did you know that if you have On-star in your vehicle, they could fix your vehicle's position so accurately that they can keep track of what intersection you are at and even if you are speeding.
Believe it or not though, computers have not been around all that long. People actually used to survive without them. My older brothers did their math homework with slide rules.

I can remember the first calculator our family owned (belonged to my brother Les). I can remember the first electronic game we had (Simon Sez) and even my first electronic watch. Computers were around, but only bigger companies owned them and personal computers didn't really come around until the mid-80's.
-I saw a computer for the first time at my mom's friend's house when I was 13 or 14. Believe me it wasn't all that impressive. They could make noises or you could write simple programs on them to cover the screen with words, no graphics though.

So back to my question, what is a computer? A **computer** is simply a machine that processes information (data). It may also store and retrieve it.
*A calculator is a computer. When I press the [5] button, **[draw picture]** an electrical connection is made and current flows into a chip, which then generates a signal of high and low, voltages which race through the circuit until they are stored temporarily or sent to a series of logic gates to be processed.

So the signals inside your computer travel around as pulses of current. (Kind of like Morse code) All computers whether they are advance programmable ones or simple computers that perform only one function all work on the same basic principles.
1. Data is stores as a series of 1's or 0's by electronic switches – a "1" is high voltage or "on" current. A "0" is a low (or no) voltage or "off" current. (The more switches there are, the more data can be stored).
2. Because there are only two positions or digits, computers use a binary code. (bi as in bicycle).
3. Each "1" or "0" stored is called a "bit" (binary digit). Eight bits in a row is called a "byte" and is used to represent a number, letter, or function key. (These are assigned according to ASCIE code) American Standard Code for Information Exchange

The first digit in each byte is left as a "0" (low V) so that the computer has an easier time recognizing a string. This leaves 7 digits to use. Since each has 2 possible positions, this gives us 2^7 possible combinations, therefore there are 128 ASCIE characters.

How to count in binary code:

		64	32	16	8	4	2	1	
Designator →	0	0	0	0	0	0	0	0	←Number "0" (Null character)
	0	0	0	0	0	0	1	0	←#2 (start of heading)
	0	0	0	0	0	0	1	1	←#3 (start of text)
	0	0	0	1	1	0	1	1	←#27 (escape key)

How would you write 97?

How would you represent a big # ? 205,675

When a computer receives an analog signal as an input it is converted to a digital signal by an analog-digital converter (ADC). The analog signal is a varying voltage in a wire created by sound into a microphone, or voltage from a thermocouple, and any number of things. (Draw Picture)

As the signal comes in, it is measured at frequent intervals, (thousands of times a second) and sent through a Comparator circuit. If the voltage is bigger than the first assigned bit, a "1" is registered (that bit line is turned on) and it opens a circuit so that the next bit is added, if it is less than the next bit a "0" is registered and it moves on.(Draw picture)

(These are not assigned at even voltage intervals and are of 16 or 32 bit input signals. (meaning you can have millions of variations)

When an output signal is created, a digital signal goes through a device known as a Digital Analog Converter **[Overhead]**

APPENDIX XVI

The Ants Go Marching One by zero, hurrah...

Even though computers seem really complex, the way that they work is extremely simple. Every process is broken down into extremely simple functions.

You can relate it to the human body, which is extremely complex simply because of the number of processes that go on inside. Most of the processes are simple reactions, but there are so many that are interdependent that the whole process of life is divinely complex. It's the same with computer memory.

(Relate to having to develop a system of counting if you only had two fingers)

The data in computers is stored as 1's and 0's using a combination of transistors and capacitors **[overhead]** (RAM) **Random Access Memory**

When the address line is supplied with current, it switches on all the transistors in that byte.

If an on current (1) comes down the data line, current (electrons) are stored in the capacitor (on). (Must be refreshed many times per second because capacitors leak charge)

To retrieve memory, the address line is again opened...

Permanent memory is stored as **Read Only Memory** (ROM) **[overhead]**

The processing of data within a computer is done with circuits known as **logic gates**. For instance, when you push the "5" button on a calculator, a series of pulses of electricity are sent along through a maze of wires like water in a canal. When this electricity comes to a gate, it is either allowed to pass or it doesn't.

The gates come in four basic types— We are going to look a three; **AND**, **EOR**, and **NOT**. **[Draw pictures and make charts]**

These gates are used to perform functions like addition and subtraction. (Multiplication is simply rapid addition) (Division is rapid subtraction)

In binary, the **rules of addition** are:

Try this: **[draw picture]**

In a calculator this process if performed in a circuit known as an **adder** that consists of several logic gates. **[Half-adder overhead] [Worksheet]**

APPENDIX XVII

Byte-Size Problems

Name ____________________

In Binary code, an eight-digit byte begins with a designator bit (0) and is followed by bits ranging in value from 2^5 power to 2^0 power. The value of each place with a "one" is added so that the byte 00001110 is equal to 14 because there are "ones" in the 8, 4, and 2 places.

D	64	32	16	8	4	2	1
0	0	0	0	1	1	1	0

1. How would you write the binary code for the number 79 which in ASCIE code stands for the capital letter O? ____________________

2. What would the number 00110110 be equivalent to? __________

3. When adding in binary code, what is the sum of two "ones"? __________
   What is the sum of two "zeros"? __________

4. How are "ones" physically stored within a memory chip until the data is needed? ____
____

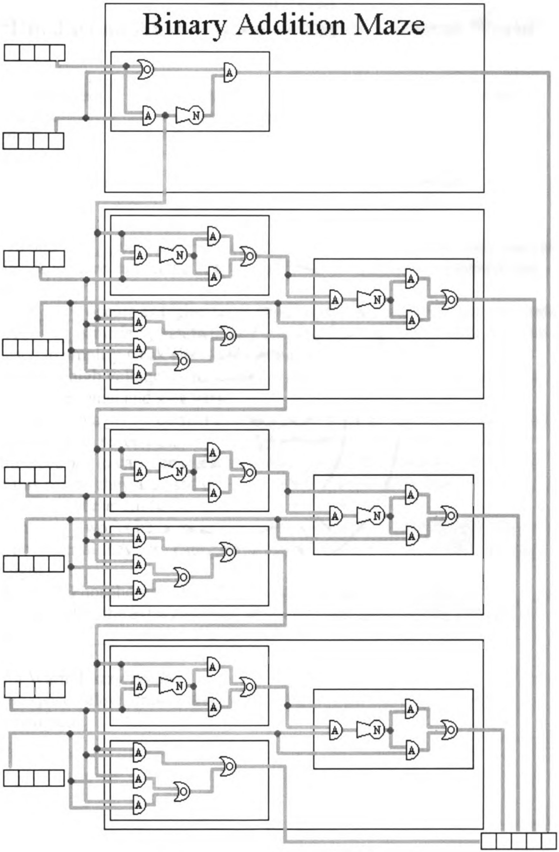
5. Fill in the tables below to show the output with the following inputs for each logic gate.

EOR		
Input		Out
0	0	
0	1	
1	0	
1	1	

AND		
Input		Out
0	0	
0	1	
1	0	
1	1	

6. What are the symbols for the following logic gates?
   AND EOR NOT

7. Use the half adder diagram on the opposite side to add the numbers 0101 and 0110. (Use a highlighter or line marker to color in the lines with high voltages and leave the low voltage lines gray.)


Binary Addition Maze

APPENDIX XVIII

"I'm Just an Analog Kind of Guy in a Digital World"

Name ________________

a. doping agent	b. byte	c. cathode ray tubes
d. diodes	e. photoelectric effect	f. AND
g. EOR	h. capacitor	i. digital
j. analog	k. NOT	l. LED
m. zone of depletion	n. n-type	o. Susannah
p. p-type	q. transistors	r. rectifiers

1. 18,000 _____, the bulky precursor to our modern transistor, were used as switches to store data in the ENIAC. (Electronic Numerical Integrator and Computer).
2. The _____occurs as high-energy photons hit a surface and eject electrons.
3. A _____ is made by sandwiching n-type and p-type conductors, and can be used to amplify weak electrical signals.
4. When a high voltage signal comes into a _____ gate it is converted to a low voltage signal and vice versa.

5., 6., & 7. In a _____ current can only flow in one direction because when it is wired with reverse bias a _____(or area where there are no "holes" or extra electrons to carry charges) develops making the resistance very high. For this reason they are used in _____ which convert alternating current (AC) to direct current (DC).

8. An _____ works because as electrons move from an n-type material to a p-type material they are "captured" by atoms and fall into an orbit, giving off light.

9. & 10. If Phosphorus, which has 5 valence electrons, is used as a _____ in a silicon wafer, the extra electrons allow the material to conduct electricity better and a _____ conductor is formed.

Extra Warm Fuzzy Points:
In the space below, draw a diagram to help explain how this quiz was photocopied.

APPENDIX XIX

Ready or Not...

Name ______________

A. On the test there will be ten matching questions using these words:

a. AND gate	b. Seebeck effect	c. capacitor
d. photo-electric effect	e. Ohm's law	f. integrated circuit
g. multimeter	h. transformer	i. Peltier effect
j. thermistor	k. n-type silicon	l. thermocouple
m. Fermi level	n. forbidden gap	o. conduction band
p. resistivity	q. transistor	r. p-type silicon
s. valence band	t. EOR gate	u. analog signal
v. semiconductor	w. binary signal	x. marks the spot
y. NOT gate	z. diode	

Like so...

1. The _____ is a range of energies (distances from the nucleus) that an electron can have and still remain in a stable orbit.

2. When current is forced through a thermocouple loop, one juncture heats up and the other cools down. This is an example of the _____.

B. There will also be some true/false questions such as...

_____ 3. A change in the average velocity of the atoms within a material will alter its resistivity.

_____ 4. If a high and low voltage signal come into a NOT gate a low voltage signal will be transmitted.

C. Not to mention some multiple choice:

_____ 5. If a hen lays one brown egg and one white egg a day, but rests on Sundays, how many eggs will you have at the end of the first week?

a. Six of one kind. b. Half-dozen of the other.

c. Insufficient data to solve. d. Enough to make a decent omelet.

D. There are some assorted problems which I haven't sorted out yet...

E. And don't forget the essay!

Use the box below to create a diagram, and use it to explain **what a thermocouple is, what it is used for,** and **how it works.** In order to get full credit, you must use at least three of the words from the matching section of the test correctly. Only applicable words will count.

APPENDIX XX

Put Your Two Cents In!

(Comments written on these surveys will be kept confidential and will have no bearing on your grade. Do not put your name on this survey.)

A. What was the best (most interesting) part of this unit? Rank each type of activity from 1-4. (1 being the choice that fits the question best.)

_____ classroom discussions/lecture _____ the marking period project
_____ laboratory activities _____ worksheets and problems

If possible, give specific reasons for your number 1 choice.

____

____

B. What part of the unit do you feel you learned the most from?

_____ classroom discussions/lecture _____ the marking period project
_____ laboratory activities _____ worksheets and problems

If possible, give specific reasons for your number 1 choice.

____

____

C. What was the most frustrating part of the unit? __________________
Why? ____

____

____

D. What suggestions do you have for making the unit better? ___________

____

____

____

APPENDIX XXI