Looking for Bohr and Einstein in "The Elegant Universe"

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Contents

Overview

The purpose of this unit is to introduce ninth grade students in the Tech Magnet Program to the strange and wonderful world of quantum mechanics and relativity as presented in Brian Green's "The Elegant Universe."

The Tech Science Course is designed to be the introductory science course in the Tech Magnet Program. Its purpose is to prepare the students for the courses they will be taking later on in their academic careers including; physics, chemistry and robotics.

In preparation for chemistry a significant emphasis is placed on understanding the structure of matter and its interactions. The periodic table of the elements is studied in depth including the history of its development and the scientists such as Demetri Mendelev and Glen Saeborg who were responsible for its development to mention only two. The relationship among the elements as presented in the various periods and groups found in the table are emphasized. While the students are not required to memorize symbols or names they are required to be able to use the table. For example, the students need to know why group one elements and group seventeen elements combine so violently and easily. They need to know why group eighteen elements combine with nothing at all and why things that we commonly call metals, such copper, silver, iron, gold are in fact metalloids and therefore transition elements. By using the periodic table students are also required to be able to determine the number of valence electrons an atom has and whether it tends to gain, lose or share these electrons.

In addition to the periodic table significant emphasis is placed on the phases of matter and how substances can transition from one phase to another and what happens when they do. Students often confuse phase transitions with chemical changes. This confusion, I believe is a result of an incomplete knowledge on their part of the law on conservation of matter and energy and how energy transfers continually occur in the natural world around us. These phase changes of course involve the movement of atoms and energy transfers but do not affect the atoms on the sub-atomic level. While the spectrum science textbook that is used for this course mentions the fact that there are subatomic particles, such as quarks, bosons, neutrinos, and leptons, ect... It makes no attempt to explain their role in the nature of matter.

In the physics aspect of the course, the concepts of force, motion and energy are dealt with on a level appropriate for this class. Students are required to be able to manipulate simple formulas such as F=ma and gpe= mgh, in order to be able to solve for any part of the formula if given the other parts. Newton's laws of motion are given careful consideration as well as his Universal Law of Gravitation . When studying motion the idea that all motion is dependent upon the frame of reference of the observer is given careful and detailed treatment. While the textbook generally limits this to the sorts of observation that would occur here on earth time is also spent developing the implications of these ideas in other parts of the universe. The Law of the Conservation of Matter and Energy is also carefully explored and the connections among such things as fusion which occurs in the sun, the photosynthesis carried on by plants and the release of stored energy as one drives an auto down the street are also looked at in some detail.

The study of the structure of matter in the chemistry aspect of this course and the nature of force, motion, and energy in the physics aspect of this course naturally to the discussion of quantum mechanics and relativity. This unit will attempt to integrate the deeper and surprising characteristics of both quantum mechanics and relativity in a way that these students would be able to both comprehend and appreciate. Since at this level, the students do not possess the necessary mathematical skills to approach these concepts in that manner, a primarily non-mathematical theoretical framework will be used.

The purpose intended for this unit is not that students will gain mastery of either quantum mechanics or relativity but that they will have a general understanding and appreciation for these milestones of scientific thought.

Rationale

In the Tech Science course the teacher is faced with significant challenges concerning student interest and motivation. Fully half of the students in the Tech Magnet Program are not enrolled because of their own personal interest but because their parents want them to be there. The Tech Magnet course is quite challenging simply because of its emphasis on technology and because there is a rather strong mathematical component. Needless to say, the motivational level is not high and the basic set of skills is not high either.

The tech magnet students seemed to be concerned primarily about clothes, shoes, hairdos and celebrities and almost completely unconcerned about anything of real consequence. The fact that the economy of the United States is becoming increasingly globalized is completely lost on the ninth grade students that I teach. It seems almost every day we hear of some business or the other that is out sourcing jobs to China, India, Taiwan or some other low wage part of the planet. In the case of India and China in particular there is a highly skilled and well educated work force that is cheap to buy and anxious to acquire some of the things that we have so long taken for granted in this country. Our students need to understand that they are not going to be competing against people in the next town, county, or state, but instead with people on the other side of the planet for whom the idea of hard work and self discipline is not a curiosity.

In addition to the Tech Magnet Course, I also teach two sections of Earth Space Science. In my Earth Space Science classes I get a significant number of ESL (English as a second language) students and many of these come from nations of Southeast Asia. Typically when they arrive their language skills are minimal and they seem to have the sorts of disadvantages which would preclude academic success, yet year after year, I find that these students find a way to succeed and by the end of the year are making A's and B's while the locals are still pretty much where they were at the beginning. Our parents used to tell us, "finish your dinner! There are children starving in China." Today we need to be telling our students, "Finish your homework! There are people hungry for your jobs." The hard work and determination of the ESL students is a perfect example of what we are up against. In the classes I teach I have found it more and more difficult to engage students in any kind of real intellectual thought process. It seems each year they possess less and less innate curiosity, and for certain their basic field of knowledge is shrinking. For example, the vast majority of incoming ninth-graders cannot multiply or divide by ten without a calculator. A significant number do not know that any number divided by itself is equal to one. And perhaps even more unbelievable is the fact of many of them do not know what the freezing point of water is in any scale; Fahrenheit, Celsius, or Kelvin. How a person manages to arrive in the ninth grade having lived in Pittsburgh the whole time, and not know what the freezing point of water is, is a complete mystery. Against the tidal forces of pop culture and society in general which is tending toward greater and greater levels of laziness and ignorance, one is faced with a rather serious question, "What to do?"

The ideas that would have in the past produced curious comments and questions from students now produce nothing but ho hum. It is not that they know everything already its just that the majority of them don't seem to care. As a professional educator I find myself constantly searching for something to militate against this tsunami of indifference and stupidity. It is my hope that the ideas and concepts found in quantum mechanics and relativity may be strange enough to stimulate their curiosity and give them the willingness to engage in the effort to find out why these things are true. I do not expect all students to be motivated and interested by these concepts, I am however, hoping for at least a majority or if not that, at least a significant minority.

We have learned an amazing amount about the nature of the universe over the last one hundred years. Indeed, our understanding of the nature of matter, time and space has undergone a revolution easily equal to that brought about by Nicholas Copernicus when he asserted that the earth was not the center of the universe. When the implications of that idea became clear, it created a storm of controversy and reaction that involved such great men as Kepler and Galileo, to name but two. The comfortable ideas, that at least those in the west had come to rely on, were completely demolished by the unpleasant reality that it was the sun not the earth that appeared to be the center of the then known universe. Isaac Newton once said, "If I had seen further than other men it is because I have stood on the shoulders of giants." One of the giants he was referring to was Galileo. It was Galileo's work with gravity and his development of the concept of inertia that enabled Newton to formulate his laws of motion and gravity. Galileo was without question a genius of the first order. But like so many of us was also his own worst enemy. Galileo's famous battles with the Catholic Church are known to almost anybody who has ever studied science at all. But the truth of the matter is that the relationship need not have been and would not have been so adversarial had Galileo been the least bit accommodating and gracious. After all, his uncle was the bishop of the city in which he lived. In essence, what his uncle and other church authorities said to Galileo was this, we know that you are correct that in fact the Earth does revolve around the sun. But we would like you to give us some time to figure out a way to introduce this idea that will cause the least amount of disruption. Galileo, however, was unwilling to agree to any such arrangement and so, wound up officially denouncing his own work, but had the last word with, "yet, still it moves."

In the 1700's Isaac Newton brought about the first great triumph of theoretical physics and mathematics. In his monumental work "The Principia" Newton laid out the mathematical framework for gravity. In order to do this he had to invent a whole new form of mathematics now known as calculus. That would have been a mind-boggling achievement all on its own but Newton did it merely as a means to an end. It is interesting to note that he made no attempt to explain why gravity existed in the first place, but simply explained with great clarity how it worked. Newton created the foundation for what became known as classical physics and provided a comfortable and reliable framework in which science could proceed with the sure knowledge that all things were ultimately explainable if investigated carefully enough. It is worth noting that fate played a part in all of this and that while Newton was a student at Cambridge, the college was closed due to the bubonic plague and Newton fled back to his family farm. It was there, as the story goes, that a falling apple interrupted Newton's thoughts. Whether this apple actually landed on his head or not, nobody knows, but in any case, it apparently set him to thinking about the idea that the force that pulled the apple to the ground was the very same force that was ordering the motions of the planets and stars.

During the eighteen-month span he spent there, he determined the wave nature of light. Newton devised a very simple but elegant experiment in which he used a prism to break up white light into its component parts that we now know as the spectrum; red orange, yellow, green, blue, and violet. By placing a second prism in any one of these parts of the spectrum he was able to determine that those could not be further broken down. Then he discovered his laws of motion and gravity, and as mentioned previously invented calculus. This brings up a rather interesting question as to whether mathematics is inherent in the structure of the universe or is simply a construct of the human mind that is overlaid on it. In other words, is math naturally there, so to speak, and something we discover, rather like picking up a beautiful shell on the seashore, or is it something that we actually make, like a sculpture producing a work of art? It has recently been determined by the discovery of a book written by Archimedes called the "The Method" that some two thousand years before Isaac Newton, Archimedes was within a gnats's eyelash of developing calculus. It is well known that about the same time that Newton developed calculus, a German mathematician, quite independent of Newton developed calculus as well. This concept, although a rather abstract one, would make an interesting basis for discussion in class provided that the students involved possessed sufficient quantities of imagination and curiosity. But getting back to Isaac Newton, I think it could be said that there has perhaps never been a more productive eighteen months in the life of anyone on this planet.

In the 1800's the great Scottish mathematician, James Clerk Maxwell, unified electricity and magnetism in four simple but profound equations. All modern electrical devices from toothbrushes to computers are founded on these equations. Maxwell was also able to calculate mathematically the speed of light. He did this by dividing the constant in the formula for electricity by the constant for the formula in magnetism and thereby calculating with precision what experimenters had been trying the determine for the previous fifty years.

About the same time two scientists at Case Western Reserve in Cleveland, Ohio, conducted what is now known as the Michaelson-Morley experiment, which was intended to prove the existence of the luminiferous ether, but which wound up proving quite conclusively that it did not exist. This caused a great deal of consternation in the scientific world but the idea that electromagnetic radiation could traverse the vast distances of space without a medium in which to do it was gradually accepted. All except perhaps, by Michaelson who to the end of his life considered this experiment his greatest failure. This was ironic because all Michaelson would have to had done was look at the work of James Clerk Maxwell and that would have told him that electro magnetic radiation was self-propagating. There were other gems to be pulled out of Maxwell's work and Einstein was the one who did it.

The beginning of the twentieth century started out with Einstein presenting his theory of relativity which claimed that gravity was not a force as Newton had said, which instantaneously reached across the vast distances of space to attract one object to another but was in fact a bending or warping of the very fabric of space itself. More than that, Einstein claimed that under conditions of constant steady motion and without a frame of reference it was impossible for an observer to determine whether motion was occurring or not. If that were not enough, he indicated that light was the only constant in the universe and always traveled at the same speed as seen by any observer. This brilliant conclusion was arrived at because he had carefully studied the work of James Clerk Maxwell and since the speed of light was derived from two constants the speed of light had to be constant as well. That of course meant that everything else was as they say, "relative."   Time as it turns out, was not a constant thing either and depends upon the motion of the observer, as well as the proximity to a large gravitational field. For example, in close proximity to a black hole at the point known as the event horizon, the gravitational force is so powerful and the warpage of space-time is so great that time stops, depending on your point of view. If a person were to fall into a black hole as he passed the event horizon he could still look out and see someone on the outside though that person could not see him until the moment that he died. To the person on the outside, he would appear to be hovering at the event horizon frozen as it were in time. The individual in question would either die because of the black hole's immense gravity or hover forever just outside of it, depending on your point of view. Though at the time few people really understood what it was Einstein had to say, he became without a doubt the most famous scientist in the world and perhaps the most famous person in his day. Not since Isaac Newton had there been a man of science who was so widely acclaimed and recognized throughout the world.

Following Einstein's revelations another group of scientists were looking in the other direction, so to speak, not at the grand sweep of stars and galaxies in the universe but at the very small. As the structure of the atom became clearer and clearer it was first believed that fundamental particles of nature were protons, neutrons, and electrons. As these were scrutinized ever more closely, scientist began to realize that there were yet smaller particles of which these were made. The most startling aspect of this emerging understanding was that certain things could not be known. Heisenberg showed us that you could not know the location and the momentum of an electron simultaneously. This seemed to fly in the face of everything that we knew about science. In fact for the last several hundred years science had progressed because it was believed that everything could be observed and understood. Heisenberg said it could not and he was not alone. A whole host of other scientist and mathematicians began to discover that at it's most fundamental, matter was random and chaotic and did not behave according to standard laws and rules but was ordered by chance. This revelation elicited one of the now more famous statements by any scientist when Einstein expressed his displeasure with this theory in the statement, "God does not play dice with the universe."

To the very real consternation of the scientific world a serious problem was developing. In every test that could be conceived and carried out both quantum mechanics and relativity proved to be true. Yet these two grand theories were in direct conflict with each other. Each essentially said that the other could not be right but the empirical data completely confirmed each. This unpleasant reality was more or less quietly tolerated and even ignored because scientists who dealt with the very large rarely dealt with the very small and vice-versa, so the "elephant" in the room could be conveniently ignored.

This all began to change in the 1970's when a new concept about the nature of the universe was developed called string theory. For the first time since the development of quantum mechanics and relativity an idea had come along which not only accommodated but also indeed united the two. This has led to a significant percentage of the scientific community working diligently and tirelessly on a theory which although beautiful in its structure and grand in its sweep has yet to have any experimental data confirm it. This is something entirely new in the world of physics. While it is true that when Einstein came up with his special theory of relativity his ideas could not immediately be tested. It was not long until experimental data began to become available which indeed confirmed Einstein's predictions, which had been developed solely from his imaginative genius and mathematics. The first piece of confirmation came in a solar eclipse that was carefully observed to see if light from apparent nearby stars would be bent by the sun's gravity as he had predicted. When this turned out to be true the "age of Einstein" had begun.

String theory on the other hand has no empirical data to support it whatsoever. While it is hoped that the new super collider that is being built in Europe will have enough power to look deep enough into the structure of matter to provide the desired empirical data, this is by no means a certainty. In his book “The Elegant Universe,” Brian Green has asserted that for at least some aspects of string theory a collidor the size of the universe itself would be needed. Since this is obviously never going to happen the question is whether some other means of confirming this seemingly marvelous theory can be developed.

It is this grand story that I want my students to know, learning just the facts, important as they may be, is simply not enough. They need to know about the people and circumstances in which they worked. Starting with the Golden Age of Greece and with men like Thales, Archimedes, Pythagoras, Euclid, and other great thinkers from this time period, I want to develop in my students an appreciation of the foundation that these people laid for the development of science and technology. It could be a very profitable tangent at this point to spend some time discussing why it was that this amazing group of scientists and mathematicians developed in this particular part of the world and at this particular time. It was this flowering of knowledge twenty-three hundred years ago in Greece that began the process, which has continued in fits and starts over the next two millennia to bring us to our present level of science and technology. The path from ignorance to understanding has not been an easy one and at times there were long intervals in which no real accomplishments were made. How and why we have arrived at our present place of understanding is in some ways as important as the knowledge itself.

<u>Objectives</u>

For the students in the ninth grade Tech Science classes my primary concern is to begin to develop a broad understanding of the nature of scientific investigation and how it works. At this point in their academic careers almost all the students I encounter perceive science as being rather a set of facts which attempts to explain events in the natural world and or a series of fun activities where they get to play with equipment and quote “ do something.” Their knowledge of the true scope and history of science is almost totally non-existent. For example, although my students have spent three-fourths of the year in a tech skills course in which they investigate among other things electricity, when I ask them if they knew or ever heard of James Clerk Maxwell, not one of them had. The same is true of Nicola Tesla. The fact that all of our modern electronics is founded on the theoretical work of Maxwell and the applied technology of Nicola Tesla makes this situation to me an intolerable one.

In addition to teaching the facts formulas and theories I endeavor to include the people and circumstances that led to the great discoveries which we now so casually use. There is a very interesting story about something called, “The War of the Currents,” which occurred at the turn of the twentieth century and involved such people as, Edison, Tesla, Westinghouse, and Steinmetz. When Tesla first arrived in this country he worked for a brief period of time for Thomas Edison. Edison was actively promoting the use of electricity in homes and businesses and was using New York City as his showplace. A problem developed between Edison and Tesla, because Edison believed that direct current was the best type to use in an urban electrical system and Tesla was convinced that alternating current was superior. According to the story, Edison promised Tesla a rather large sum of money ($50,000) if he would upgrade and improve his generating system. Tesla did it, but Edison refused to pay him the bonus that was promised and they parted company. Tesla was once again out on his own and down on his luck, but a famous Pittsburgher stepped in to champion the cause of alternating current. That was of course George Westinghouse. Westinghouse purchased Tesla's patents for alternating current generation systems and like Edison, began to promote their use and development. As we all now know, Tesla's A.C. did in fact prove to be superior to Edison's D.C. and is the type of electricity that is used in homes and businesses throughout the world. This is just one example and briefly put here, of the many fascinating stories that are connected with the development of science and technology that we use everyday.

Students will be able to not only understand the basic principles of electricity and magnetism and the interrelationship between the two, but they will also know that these two phenomena are in fact two manifestations of the same thing. At each and every point in the course emphasis will be made showing how electricity and magnetism are tied together and how both of these in their fundamental formulations, so closely parallel that of gravity. Although in this course we do not go into any detail concerning the strong and the weak forces beyond mentioning that they exist and what it is that they do, students are reminded that these forces as well are in all likelihood an outgrowth of an underlying force and yet again simply a different manifestation of it. It is in this aspect of the course that the introduction of the principles of quantum mechanics is most easily achieved. As we delve into the interrelatedness of electricity and magnetism it is natural and reasonable to look for the underlying causes which lead us directly to the subatomic world and hence the world of quantum theory.

While it is impossible at this grade level to approach quantum mechanics from a mathematical standpoint the basic ideas and concepts can be presented and discussed to help the students see at the most basic level the fundamental connections among all forces and matter.

In addition to being able to name protons, neutrons, and electrons, and describe the function of each, students will also be able to name some of the more prominent sub-atomic particles, which make up protons and neutrons, such as quarks, bosons, leptons, neutrinos, etc. Students will also be introduced to the idea of a force particle such as gluons and how it functions, as opposed to the more common idea of a force as a mysterious something that affects something else at a distance.

In chapter 9, which deals with Newton's laws of motion and gravity, my objective is that students will be able to understand, verbalize and apply the laws of motion, but also to understand that whether or not motion occurs, in what direction, and to what degree is entirely dependent upon the frame of reference of the observer. Even such things as the passage of time and the mass of an object become dependent upon the observational position. Students will be able to not only articulate the universal law of gravitation as conceived by Newton, but also will be able to explain gravity as a warpage of space time as described by Albert Einstein in his "Special Theory of Relativity." Students will be able to state that because light speed is the only constant in the universe that everything else is "relative." As in the case of quantum mechanics, where the mathematics governing the particulars of relativity are beyond the capability of ninth grade students, grasping the general concepts is not. As a result, relativity will be approached from a conceptual as opposed to a mathematical standpoint as was quantum theory.

The addition of these two theories, quantum mechanics and relativity, into the ninth grade tech science program is meant to provide a means to broaden the view and deepen the understanding of the ninth grade students. It is not supposed that these studies will create large numbers of theoretical physicists but rather give the students a deeper appreciation for the truly strange and wonderful nature of the world around them. It is also hoped that this strangeness may, in some cases, be a spark that will ignite their curiosity and lead them to pursue areas of study, which they hitherto may not have considered.

Strategies

The Tech Science Course begins with the nature of science in which the following objectives are discussed: Beginning with the main branches of natural science and their relationship to each other, the relationship between science and technology, developing the ability to distinguish among facts, theories and laws, and explaining the roles of models of mathematics in scientific theories and laws. I endeavor to spend a fair amount of time discussing the relationship between science and technology because although students understand that there is some connection between these two, they don't really know what it is. This of course leads naturally to facts, theories, and laws and again, although they generally have some vague idea about these they are not clear as to what they are. To them a theory carries as much weight as a law and facts are part of both,. "so what's the difference?" It is in this opening part of the course that for probably the thousandth time we bring them to the scientific method of problem solving. I like to introduce this idea by creating a problem for them to solve. I use an illusion as a means to do this. I will take two handkerchiefs, one large and one small, and explain to them at I am going to make the smaller handkerchief to appear to disappear into the larger one. I explain at the outset that this is merely a trick and of course no magic is involved at all. I call on them to use their powers of observation to see through the trickery and tell me how it's being done. I will repeatedly make the small handkerchief disappear and reappear trying to respond to as many of their (hypothesis) as possible. For example, students often suggest that I am hiding the small handkerchief up my sleeve. I will then roll up my sleeves to the elbow and conduct the experiment again. Another suggestion that I get is that I am hiding it in my pocket somehow. I then turn my pockets inside out and repeat the procedure. The illusion is created over and over until finally someone figures out what is actually happening. This provides a terrific opportunity to talk about the differences between appearances and reality and it is in the process of the discovery that we make a list of steps, which we eventually resolve into the scientific method of problem solving.

Having established for them the process by which science advances we then move on to units of measurement. Although these students have been presented the metric system over and over again almost none of them know anything about it except for the name. I then go through the process of developing the metric system for them both historically and presently starting with the distance from the pole to the equator as the standard used to create the meter and from the meter all the other units of the metric system. Ample opportunity is given to practice using metric units for various sorts with an emphasis on learning that the metric system is based on powers of ten which one would think would be a great advantage except these students cannot multiply and divide by ten in their heads. The importance of memorizing the prefixes as a key to the metric system is also presented. In conjunction with the metric system, scientific notation is also presented and they're given opportunities to develop their skills in this area by solving various problems.

Having laid the foundation for doing science by using a logical, systematic method of problem solving, we then move on to the nature of matter. It is here that the atom is introduced, the idea of atoms combining chemically to form compounds, and what such things as substances and mixtures are.

We then go on to matter and energy using the kinetic theory to describe the properties and structures of the different states of matter. We talk about the states of matter and how energy transfers are involved in each and of course the law of the conservation of matter and energy. The students are shown demonstrations that prove for example, the law of the conservation of matter.

Briefly put, it works this way. A candle is placed on a balance and the balance is adjusted so that the balance pans are even. The candle is then lit and burned for a couple of minutes, until the balance is no longer balanced. The process is then repeated, but this time the candle is inside a jar that will capture all the gasses produced as the candle burns. The candle is lit and allowed to burn for the same amount of time as it was previously, but in this case the balance remains balanced because all the matter that previously had escaped into the atmosphere was contained in the jar. By this and other demonstrations we are able to make clear to the students that laws such as, the conservation of matter and energy are in fact true.

We distinguish between the chemical and the physical properties of matter as well as the chemical and physical changes of matter and investigate what properties give certain types of matter certain advantages for one use as oppose to another. For example, why a piece of plywood makes an excellent structure for a wall but would make a very bad window and why glass though an excellent window would be bad choice for the body of an automobile, unless it was fiberglass.

After investigating the nature of matter in the manner just discussed we go on to atoms and the periodic table. Here we cover such things as what are atoms, what is in an atom, models of the atom, and where and how these models were developed. It is in this section as we discuss the nature and structure of the atom that some of the aspects of quantum mechanics could be introduced. While the text book talks about atoms being made of protons, neutrons, and electrons, and giving some detail about each such as mass, charge, and in the case of electrons, orbitals and orbital structures, it makes no attempt to go any deeper than this. While this is no doubt a reasonable approach given the age and background of the students I feel that an opportunity is being missed here to stimulate curiosity and fascination by introducing the strange world of sub-atomic particles. It is here that the introduction of things like quarks, neutrinos, leptons, force particles, and so on, could perhaps be an opening to stimulate curiosity that simply does not occur with a more typical science that the students are familiar with.

In addition, examining the lives of some of the scientist involved in the development of quantum mechanics can be a means of catching their interest because there was nothing dull or boring about men like Schroedinger, Heisenberg, Bohr, and many others. At this point we explore in depth the periodic table of the elements. The importance of the groups and periods, the orderly marches of atomic numbers from hydrogen up through the artificial elements, the work of valence electrons and the relationship between atomic and mass numbers are explored. We investigate at some length the families of the elements and why such things as lithium, sodium, potassium, and rubidium go together and are completely unlike other elements such as helium, neon, argon, and krypton. While constantly emphasizing that although these atoms are in fact different and behave in different ways they are made from exactly the same parts and pieces.

Once we have covered the fundamentals of matter we then go onto the subject of motion. We talk about motion in its simplest terms as being translational, rotational, or vibrational and introduce the concept of speed as a relationship between distance and time. We present the ideas of acceleration and force. We go on to say that acceleration is a change in velocity divided by the time interval in which the change has occurred. We introduce the concept of forces as the means by which motion and acceleration can take place. And it is here that we introduce Newton's laws of motion and law of gravity. It is in this unit that the perfect opportunity presents itself to discuss relativity because as Einstein so brilliantly determined all motion is relative and depends upon the point of view of the observer, mass and time depend upon the point of view of the observer as well. It is in this section of the course that I would make use of both Brian Green's "Elegant Universe" and Stephen Hawkings "A Brief History of Time," as well as Nova's "Elegant Universe."

The challenge here will be to weave together the material presented in the text concerning the nature of matter and force, motion, and energy, with the ideas of quantum mechanics and relativity. I see this as a continual ongoing process where as each aspect of the nature of matter and things like acceleration and gravity is studied, a constant reference back to quantum mechanics and relativity could be made. By providing supplemental materials for reading, watching media such as Nova "The Elegant Universe," the students will be encouraged to explore the rich and wonderful depth of human knowledge concerning the true nature of the universe.

Classroom Activities

At various times throughout the curriculum and where appropriate, readings from supplemental texts such as Brian Green's "The Elegant Universe," and Stephen Hawkings "A Brief History of Time," and "The Universe in a Nutshell" will be required. Students will be asked to provide a written response explaining what it was the reading meant to them and how it fits into what we are currently studying.

In addition to supplemental readings, selected programs from the mechanical universe featuring Doctor Goodstein from Cal Tech will be viewed and reflected upon. And of course, "The Elegant Universe" as presented on PBS, Nova series will be viewed as and when appropriate.

Students will conduct an experiment during the section on gravity showing that even small objects exert gravitational forces. The experiment is quite simple and works like this: A thin string will be attached to a bar extending from a ring stand or suitable supporting structure to which will be attached a rod approximately eighteen inches long in such a way that the rod is free to rotate. On each end of the rod will be placed a led sphere having a mass of two hundred grams. This whole apparatus will be suspended off the table at a height of approximately two centimeters. Once the rod and the spheres are balanced and motionless, two larger masses, spheres of one kilogram each will be placed adjacent to the spheres on the rod but on opposite sides at a distance of approximately two centimeters. It will then be observed that the rod with the spheres attached which was formerly motionless now begins to move so that the two hundred gram spheres on the end of the rod are moving towards the one kilogram spheres sitting on the table. This will demonstrate conclusively that even small objects possess gravity.

When studying force, motion and energy the conservation of angular momentum will be demonstrated by having a student sitting on a rotating stool with a relatively heavy object such as a textbook or small hand weight in each hand. The student will then be rotated and by moving his arms closer to or further away from his body, he can speed up or slow down.

In the section on gravity when the conflict between quantum mechanics and relativity is discussed, string theory will be introduce as a means of unifying these two concepts as Maxwell unified electricity and magnetism. A guitarist will be invited to the class to explain briefly how the instruments works and demonstrate the fact that a particular string can provide a whole variety of sounds depending on its length and how much energy is put into it. This illustration will then be used to help students comprehend how the different vibrational modes of the strings of string theory could give rise to different forces of particles even though they are essentially the same.

In the section dealing with the relative nature of motion, mass and time, students will be shown Hubble Space telescope photos of distant galaxies and told that the light from these galaxies left in hundred of millions or billions of years ago. And since the galaxies are moving they will be asked to speculate where those galaxies might be now or even if they still exist. The object here is to help them understand that even if we observed things carefully we cannot always see them as they are but rather only as they once were.

Bibliography

Asimov, Isaac. Visions Of The Universe. Montrose, California: Carl Sagan Productions, Inc., 1981.

Bahn, Paul G. 100 Great Archaeological Discoveries. New York: Barnes & Noble, Inc., 1995.

Dobson, Ken, John Holman ,and Michael Roberts. Spectrum A Physical Approach. Vol. 1 Austin: Holt, Reinhart and Winston, 2001. 522-555

Green, Brian. The Elegant Universe. New York: Random House, Inc., 1999.

Hawkings, Stephen. A Brief History of Time. New York: Bantam Books, 1988.

Pasachoff, Jay M.. Astronomy: From The Earth To The Universe. Saunders College Publishing, 1998.

Seeds, Michael A. Horizons, Exploring the Universe. Belmont, California: Wadsworth Inc., 1989.

Appendix A: Content Standards for the Pittsburgh Public Schools.
The following standards are addressed in this unit.

Reading, Writing, Speaking and Listening:

1. All students use effective research and information management skills, including locating primary and secondary sources of information with traditional and emerging library technologies.

3. All students respond orally and in writing to information and ideas gained by reading narrative and informational texts and use the information and ideas to make decisions and solve problems.

5. All students analyze and make critical judgments about all forms of communication, separating fact from opinion, recognizing propaganda, stereotypes and statements of bias, recognizing inconsistencies and judging the validity of evidence.

6. All students exchange information orally, including understanding and giving spoken instructions, asking and answering questions appropriately, and promoting effective group communications.

Mathematics.

1. All students use numbers, number systems, and equivalent forms (including numbers, words, objects and graphics) to represent theoretical and practical situations.

2. All students compute, measure and estimate to solve theoretical and practical problems, using appropriate tools, including modern technology such as calculators and computers.

3. All students formulate and solve problems and communicate the mathematical processes used and the reasons for using them.

7. All students evaluate, infer and draw appropriate conclusions, from charts, tables and graphs, showing the relationships between data and real-world situations.

Citizenship

8. All students demonstrate that they can work effectively with others.

Science and Technology.

1. All students explain how scientific principles of chemical, physical and biological phenomena have developed and relate them to real-world situations.

2. All Students demonstrate knowledge of basic concepts and principles of physical, chemical, biological and earth sciences.

3. All students' use and master materials, tools and processes of major technologies, which are applied in economic and civic life.

4. All students explain the relationships among science, technology and society.

5. All students construct and evaluate scientific and technological systems using models to explain or predict results.

6. All students develop and apply skills of observation, data collection, analysis, pattern recognition, prediction and scientific reasoning in designing and conducting experiments and solving technological problems.

9. All students demonstrate basic computer literacy, including word-processing, software applications, and the ability to access the global information infrastructure, using current technology.