INTEGRATED SCIENCE I

Salem International University

INSTRUCTOR: James E. Beichler, Ph.D.

TEXTBOOK: *Integrated Science*, by Bill W. Tillery, Eldon D. Enger and Frederick C. Ross

COURSE DESCRIPTION: This course serves as an introduction to the ideas, concepts and practices which form the basis of modern science. In this first section of the Integrated Science course, the areas of physics, astronomy and geology will be covered. Science began nearly two and a half millennia ago in ancient Greece. Physics was the first of the sciences and is still considered the most basic of all the sciences. In physics, the phenomena, events and happenings of which our physical environment consists are logically analyzed into their most fundamental components; matter and motion against the common background of space and time. Ancient philosophers carefully observed all in the world around them, including the stars in the night skies. Observational astronomy was one of the motivating factors in the earliest development of concepts of change and motion in physics and science in general, even though astronomy is an independent science in our own time. The separation of science into many different branches is a later development. That part of astronomy which involves an explanation of the motions of planets stars and other heavenly bodies is also called astrophysics. So, after our study of the basic concepts of motion, the forces which make material bodies move, the energies involved in such processes, the electromagnetic forces and light, we will study structure of the basic units of matter, the atom and the nucleus. Such a study of the microscopic elements of our physical reality actually brings us back the the structure of the universe as a whole as well as the nuclear processes which fuel the stars themselves. So we will then study the astronomy of the universe, galaxy and solar system. After we study the planets in our own solar system, we will continue to specialize our study on our own planet, the earth. In particular, we will look at the forces which shape the surface of our earth as well as how the rocks which make up our immediate environment came to be formed. This will complete our course, but Integrated Science will not be finished. All of the sciences are related in a single whole, yet chemistry and biology have been left for the second course of Integrated Science. That particular separation of the sciences is completely articifial, made as a convenience for our studies, since all of the sciences form a single comprehensive whole.

GRADING METHOD: This course will consist of two internet lectures per week over an eight week period. After the eighth lecture, a midterm exam will be given over the internet. A final exam will be given in a common area with a proctor present at the end of the eight week course. In the text of each chapter of the textbook, "activites" are listed. These "activites," as well as others to be posted by the instructor over the internet, will be completed individually by the students and written reports submitted to the instructor for correction, comment and grading. These activites are provided to replace the laboratory exercises which usually accompany a science course such as this one. Problems from the textbook as well as new problems posted on the internet will also be completed by the students with the answers submitted to the instructor. And finally, each chapter of the textbook includes a section on "questions for thought." These questions, and others posted by the instructor, will form the basis of an ongoing internet discussion by the students and instructor. Student responses and contibutions to the discussion for these threaded questions will also be considered in determining the student's grade for this course. Hand-outs and further explanations of requirements and procedures will be given during the course as necessary. So, there are four parts to this course which the student will need to complete for a grade:

Threaded Questions	15%
Activities	20%
Midterm exam	25%
Final Exam	40%

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Each student will receive a letter grade based upon the following common standard:

A	90 - 100%
B	80 - 90%
C	70 - 80%
D	60 - 70%
F	Below 60% .

LECTURE SCHEDULE:

WEEK 1

Lecture I : Introduction to Science including Chapter 1: The World Around You
Lecture II: Chapter 2: Motion

WEEK 2

Lecture III: Chapter 3: Patterns of Motion
Lecture IV: Chapter 4: Energy

WEEK 3

Lecture V: Chapter 5: Heat and Temperature
Lecture VI: Chapter 6: Wave Motions and Sound

WEEK 4

Lecture VII: Chapter 7: Electricity
Lecture VIII: Chapter 7: Magnetism
MIDTERM EXAM covering Chapters 1 through 7

WEEK 5

Lecture IX: Chapter 8: Light
Lecture X: Chapter 9: Atomic Structure

WEEK 6

Lecture XI: Chapter 15: Nuclear Reactions
Lecture XII: Chapter 16: The Universe

WEEK 7

Lecture XIII: Chapter 17: The Solar System
Lecture XIV: Chapter 18: Earth in Space

WEEK 8

Lecture XV: Chapter 19: The Earth and Chapter 20: The Earth's Surface (only to page 500)
Lecture XVI: FINAL EXAM covering all chapters and course material

Lecture:
INTRODUCTION

Science is the logical study of events and phenomena that occur in the world in and around us, including both our immediate and extended environment. Science is based upon reason and was originally founded as a philosophical pursuit, although intuition is an important element in the development of science and scientific concepts. Science attempts to explain how events occur and find the causes of natural phenomena.

Science, in its earliest recognizable form, began in Ancient Greece nearly 2500 years ago. The first notable philosopher, who could be called a scientist although that term was not used in his day, was Aristotle. Aristotle was a keen observer of nature. He inherited the notion that our world could be explained by the changes that we see all around us from earlier philosophers. So the concept of change became the logical basis of all science. The most general change that we normally see in our everyday lives is the change in position of a material object, which we define as motion. This particular form of change is so common that it became the basis of physics.

Today, we group the sciences into several categories, but those divisions are human made, not part of nature itself. For example, there are three broad categories of science; the physical sciences, the biological sciences and the mental sciences. The physical sciences consist of physics, astronomy, chemistry, geology, oceanography and meteorology, with numerous smaller disciplines. The biological sciences consist of biology, anatomy, physiology, medicine, and again, numerous other branches, while the mental sciences would include psychology, psychiatry and related subjects. All of these divisions have evolved as science progressed from its roots so long ago, but nature does not distinguish between these disciplines. So, there are areas of crossover between the sciences. For example, a physicist may study astrophysics, while an astronomer who traditionally observes stars, will study physical astronomy which explains how stars and planets move and their physical properties, literally how the heavens work. But astrophysics is the same as physical astronomy; they only differ from the perspective of the two different, but related, disciplines of study. Similar cases occur for the other sciences, such as physical geology and geophysics, physical biology and biophysics, physical chemistry and chemical physics, biochemistry and chemical biology. It is far more realistic and accurate to say that we can view science as a single whole, which we can call integrated science.

PHYSICS

Physics is the oldest and, in the minds of most scientists and scholars, the most fundamental of the sciences. This means that most of the other sciences can be broken down, or reduced, into physics at the lowest level of physical reality. Physics can be thought to have started with Aristotle, who wrote a book titled *Physics* in 350 B.C. E. The text of Aristotle's book can be read or downloaded from the Internet at http://classics.mit.edu/Aristotle/physics.l.i.html . The ancient Greek word 'physics' translates as 'nature,' so Aristotle's book dealt with the 'nature ' of objects or how objects moved and interacted with 'nature' in a more general sense. In his book, Aristotle attempted to explain phenomena in the world around him by using the simplest and most fundamental terms that he could find, matter and motion. So physics has come to be the science that explains our world in terms of matter, motion, and 'matter in motion.' Physics, at its deepest level, seeks to discover the physical **properties** of nature and reality itself.

Science has progressed quite a bit in the 2,500 years since Aristotle, but that progress has been very slow until recently. Aristotelian physics dominated philosophical thought until the seventeenth century when the Aristotelian view of nature was finally overthrown during the Scientific Revolution. Today our worldview is more complete, but physics remains essentially the same task. So we can define now physics as a logical study of the events and phenomena in nature which is conducted by reducing the world around us into its most fundamental components, matter, motion, and 'matter in motion,' against the common background of space and time. Dictionaries commonly use a similar definition, such as 'physics is the science that deals with the interactions of matter and energy.' Such a dictionary definition differs from this definition only in its degree of completeness, since energy is just one way of packaging 'matter in motion,' as is momentum, while both energy and momentum are related to the forces that make matter move. All of these concepts will be studied in greater detail as we learn basic physics in the coming lessons.

The method by which science develops or evolves, **the scientific method**, is of greater importance at this time. The scientific method, and its corollary, the experimental method, was a development of the Scientific Revolution. All of science is based upon the careful observation of nature and the world around us. So observation is the first step of the scientific method. But before we can go further than just making simple observations, we must define the physical quantities that we are observing so that we can measure them accurately. Once we have measured the quantities under study, which amounts to collecting the **data** that forms the backbone of science, a scientist will look for patterns of repetition in the data. The scientist will attempt to answer the question, how do events occur time and again in the same manner given the same conditions? Noting these patterns the scientist will form a **hypothesis** to explain how the event proceeds or occurs and thereby develop an experiment to test that hypothesis. If the experiment is successful, the hypothesis is accepted and expanded to include a greater number of conditions. If the hypothesis proves correct under many different conditions, it becomes a theory, and if the theory successfully explains an ever-expanding broad range of natural phenomena, then it becomes a **law** of nature. In some case, a theory describes a specific set of relationships that are even more fundamental than a law of nature, such as the conservation of energy, which constitutes a **principle** of nature. Scientific laws may change as more data is collected, new phenomena are discovered and more accurate measurements are made, but a scientific principle is a more powerful and unchanging concept and thus should not change.

However, if the initial experiment was unsuccessful and the original hypothesis proved false, the hypothesis can be either discarded or amended as warranted. New experiments are conducted to prove or disprove the amended hypothesis. In some cases, when a hypothesis proves false upon experimentation, the scientist may go further back along the line of development, redefine the initial physical quantities and measure them again before developing the new hypothesis for testing. This whole process is known as the scientific method, and the **experimental method** is an essential part of the overall scientific method. Another description of the scientific method can be found at http://phvun5.ucr.edu/~wudka/Physics7/Notes http://www/node6.html#SECTION02121000000000000000 and http://home.xnet.com/~blatura/skep_1.html or http://teacher.nsrl.rochester.edu/phy_labs/AppendixE/AppendixE.html. Different scholars will state the method in slightly different terms, since each person emphasizes a different part of the method, but all the definitions prove essentially the same when they are carefully studied.

The scientific method is an essential tool in the development of any area of science, but it is not the only tool. Mathematics is also an essential tool, as is the experimental method itself. Mathematics is often used in conjunction with the concepts, theories and laws of nature to model physical events and phenomena without conducting actual physical experiments. The concepts, hypotheses, theories, principles and laws of nature are often expressed as mathematical formulas that are also shorthand forms of the ideas themselves and thus act as small models of the actual physical events or phenomena that the laws describe or explain. For example, if you push a material object, it will move with increasing speed. As a formula, this would be stated as $F = ma$, where F is the force that is the push, m is the mass or amount of material in the object and a is acceleration the change in speed of the object. $F= ma$ can be translated as a push (F) causes (=) a material (m) object to change speed (a), and thus provides a simple mathematical model of a physical event. Yet introducing such a concept presupposes that force, mass and acceleration have been carefully defined.

Definition and measurement are also very important factors in science. In order for science to work, everyone, no matter where they are or what they are doing, must be able to derive the same experimental results given the same conditions. Otherwise, the laws and principles that make up science would not be universally applicable and science would fail. So, when specific physical quantities are defined, they must be described in terms of universally accepted units of measurement. That way, no matter who measures the length of a meter stick, and no matter where or when it is measured, everyone's meter stick will always be the same length. The standardization of units has been a primary responsibility of science as long as science has existed. Today, our world has grown closed, so we use the same standard units of measurement all over the world. This system is called the SI, or the 'Systeme Internationale,' which is the accepted French name. Otherwise, the system is commonly called the metric system. Another system, which is nearly as popular, is called the English system, but it is not internationally accepted.

In both cases, standard measurements are given for any defined quantity. For example, a length or distance can be given in meters or feet, according to the metric and English systems. The metric unit of the meter can be converted into larger or smaller units by adding a prefix since the metric system is based upon multiples of ten. So a centimeter is one one-hundredth of a meter, and a kilometer equals one thousand meters. The English system is not so convenient since it is not based on units of ten. Twelve inches equal one foot and five thousand two hundred and eighty feet are equal to one mile. However, we can convert from one system to another, as long as we are talking about the same quantities, such as length, by using conversion factors. In other words, one-inch equals 2.54 centimeters, or one mile equal 1,604 meters. In many cases, converting from one system to another is an important detail, since the United States still uses the English system, while the rest of the world has now converted to the metric system. The units of time are very nearly the only exception and the second is used as the basic unit in all systems of measurement. Nor has the measurement of time been based upon multiples of ten, except in Star Trek (Star Date 2301.4).

The following table of common quantities and their corresponding units of measurement should prove helpful, although the list is neither comprehensive nor complete.

	SI or metric	English
Length	meter (centimeter)	foot (inch)
Distance	meter (centimeter)	foot (inch)
Speed	meter/second	foot/second
Mass	kilogram (gram)	slug
Force (or weight)	Newton (dyne)	pound (ounce)
Energy	Joule (erg)	
Volume	cubic meter	cubic foot
Density	kilogram/cubic meter	
Time	second	second

Several of these units are compound, and thus the quantities that they measure do not represent fundamental properties in physics. The four fundamental quantities are length, time, mass and charge. These units cannot be further reduced to combinations of other more fundamental units. For example, speed is a compound of the units of length and time, so speed is not a fundamental quantity. In fact, speed is the most basic quantity that exists for developing a physics of motion, but it incorporates changes in both length or distance and time.

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Writing Assignment: Complete the 'Activities' on page 11. Write a report about your results, making it as complete as possible, and send a copy of your report to the instructor via email. The report is due by Friday at the end of week 1.

Discuss the various 'Questions for Thought' at the end of the chapter and submit your written responses to the instructor via email by the end of week 1. The best of the responses will be posted on the Internet for the whole class to read and comment upon as threaded questions and sources for further discussion. Your participation will be graded.

Complete the 'Parallel Exercises' on page 21. Group A solutions and answers are given in the back of the book. Group A problems are for practice. Submit the answers (only) to the Group B problems to the instructor by Friday at the end of week 1.

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Special question for group discussion on the Internet [Participation will be graded]

Pretend you are an ancient Greek philosopher attempting to explain the world around you by the changes that occur. Remember, you do not have the advantage of today's advanced knowledge and culture. What would you assume to be the most fundamental properties or quantities that could be used for this purpose? Is there anything more fundamental than matter and motion? Are there things in nature that cannot be explained by resorting to matter, motion and 'matter in motion'? Submit your comments, conclusions and ideas to the instructor via email for posting on the Internet and further discussion.

LECTURE 2:

MOTION

The development of a simple concept of speed to represent motion in early physics was essential, but Aristotle and later 'scientists' failed at the task. Our modern concept of speed as distance/time took a long time to develop. The Greek philosophers thought it was impossible to divide one quantity by a totally different quantity and thus derive a completely new quantity. It would be like taking three apples out of a bag of twelve oranges to get four tomatoes, even though twelve divided by three is four. So they would never have divided a distance by time to get a speed, let alone divide twelve kilometers by three hours to get a speed of four kilometers per pour as we do today. It was not until the beginning of the thirteenth century that a true concept of speed emerged.

Even then, we are saddled with three different notions of **speed**. Commonly, speed is just a distance traveled divided by the time to travel that distance. For example, if you drive to your grandmother's house, which is fifty miles away, in fifty minutes, your speed would be sixty miles per hour. But this is just an average speed for the whole trip, and the figure does not necessarily represent your speed at any given moment during the trip. So a more accurate concept of speed from moment to moment was needed. Today, the above calculated speed would be called the average speed, and in the simplest case where the speed is constantly set at the same value, say by a cruise control on the car traveling on a flat surface, the average speed can also be considered a constant speed. So we already have two different concepts of speed with which to deal.

Yet these two concepts suggest a third concept; how do we deal with a non-constant or varying speed? For this, we need to develop the concept of an instantaneous speed, or the speed of motion at any given moment during the total motion. This last concept is necessary so that we can see how speed changes, and a changing speed is called acceleration. Defining instantaneous speed gives us the proper mathematical tool to describe accelerations. If we consider average speeds, but look at them over ever shortening lengths of time, we finally come to an average speed over a short enough time period to be called an 'instant' or 'moment' of time. This would be our instantaneous speed, literally an average speed over an amount of time approaching zero time, getting smaller, but not zero time. The speedometer in a car, motorcycle or other vehicle measures instantaneous speed. We use the letter 'v' to denote a speed because speed is sometimes called a velocity. But technically, in physics, a **velocity** is more than just a speed. Velocity is a speed plus the direction of travel.

With the concept of instantaneous speed in hand, we can now define **acceleration** as the change in speed, such that we can look at the difference between two speeds, a final and initial speed, and divide them by the time interval between them. This would give us an average or constant acceleration covering the whole time of the change. At this level of physics, we do not need to consider the concept of a changing or varying acceleration that would need a more comprehensive mathematical base to discuss, so we only consider the simpler case of constant accelerations. Even the concept of a deceleration, a slowing of speed, is different in physics than in common conversation. When we work out the mathematics for a given situation, we could get a negative acceleration if the final speed was less than the initial speed. So negative acceleration is the mathematical expression of a deceleration or decreasing speed.

Now that we have a basic understanding of the concept of motion, as defined by speeds and accelerations, we need to consider real motions. Many real motions occur in two dimensions. For example, if we throw a ball to a person standing ten meters away, we throw the ball higher than the person catching the ball because we know that the ball will fall as it moves toward the person. The ball follows a parabolic or curved path. This path or trajectory is a perfect example of a two dimensional motion. Not all motions follow a straight path, along a straight one-dimensional line. To understand a real two-dimensional motion we must look at the combination of the motion's two one-dimensional linear components, the horizontal and vertical motions which combine to make up the two-dimensional path of motion. The horizontal component lies along the flat surface of the earth and has no external forces affecting it, while the vertical component, the up and down motion relative to the surface of the earth, is affected by gravity. The natural force of gravity acts ONLY in the vertical direction. The final trajectory is the combination of the constant horizontal speed and the constantly varying vertical speed that first decelerates as the ball moves upward and then accelerates due to gravity as the ball falls downward. Together, these two components combine to give the ball its parabolic or curved motion as it travels toward the person that will catch it.

It is easy to work with the horizontal speed because it is constant, however we must further analyze the vertical speed, which incorporates a gravitational acceleration. We know that a body dropped from some height will fall straight down, without being otherwise pushed or pulled, due only to the action of gravity. The correct description for a material body falling directly to the ground was first given by Galileo in the early seventeenth century. His description is usually called Galileo's Law of Free Fall or just the **Law of Free Fall**, where free fall means that no other forces except gravity are acting on the failing object. Another explanation of free fall can be found at www.geocities.com/Athens/Academy/9208/u2l3e.html and www.vjc.moe.edu.sg/dept/physics/applet/freefall/m_gracc_h.htm.Galileo was the first scientist to discover that the distance that an object falls depends on (or is proportional to) the square of the time during which the object falls. For instance, if an object falls ten units of length in one second, it will fall forty units of length (or two squared times ten) in two seconds and ninety units (three squared times ten) in three seconds. An object will fall four times as far during the second length of time, nine times as far during the third length ot time, sixteen times as far during the fourth length of time, and so on. We can be more exact and write this relationship as

$$d = ½\, gt^2.$$

The quantity '½ g' is a constant number called a constant of proportionality, where '**g**' is the acceleration due to gravity. 'g' has a value of 9.8 meters/second^2 at the surface of the earth. 'g' varies with altitude, or distance from the center of the earth, but it varies by so small an amount over the relatively small distances between the lowest and highest points on earth's surface, that we can consider the value constant for whole of the surface.

The value of 'g' means that an object will fall gaining a speed of 9.8 meters/second after the first second and gain that same amount of speed during each second after the first. So, after two seconds, a free falling object will reach a speed or 19.6 meters/second under ideal conditions, and 29.4 meters/second after three seconds. The ideal conditions would mean in a vacuum where there is no air resistance to the motion, so real speeds at the earth's surface would be less than the above.

It is important to note that there is no representation for the amount of matter or mass of the object in the above formula representing free fall. Free fall or acceleration due to gravity is independent of the mass of the falling object. This means that objects of different mass fall at the same rate in ideal cases where we can neglect the effects of air resistance. Galileo was the first to discover this property of gravity and he made that discovery before he found the law of free fall. According to the accepted theory during Galileo's lifetime, the Aristotelian theory of motion, a denser object will fall faster than a less dense object. While Galileo was a student he had a friend drop two objects of different masses and densities from the Leaning Tower of Pisa while he stood at the bottom and observed the results. Even though the two objects had different masses, they hit the ground at the same time, demonstrating that Aristotle was wrong and gravity affects different masses by pulling them at the same rate. This is the same as saying that 'g' is the same for all material bodies on the earth's surface. You can easily repeat this experiment and prove the fact for yourself. In fact, when American astronauts first traveled to the moon, they repeated this experiment in the airless environment of the moon, to show that Galileo's original discovery was valid somewhere other than the surface of the earth. It is always important to demonstrate the universality of our physics and laws of nature.

When the law of free fall (describing vertical motion) is combined with the rules governing constant horizontal motion, projectile motions were described for the first time, which was Galileo's primary objective. Real two-dimensional motions follow parabolic, circular, elliptical or similar paths and all of these paths of motion are combinations of two components, which we are here calling the horizontal and vertical. Go to www.phys.virginia.edu/classes/109N/more_stuff/Applets/ProjectileMotion/jarapplet.html for an example of a simple projectile motion. This model of motion is so powerful that it can describe everything from baseballs to footballs and on to planets and the stars in the heavens themselves, although it was up to Newton to apply these laws to the heavens a half century after Galileo.

By this time, it was becoming evident to Galileo and a few other great thinkers that the old definitions of matter were not working. Aristotelian physics was proven to be failing so the older theories of **force** causing motion were inadequate. New ideas on the relationship between force, matter and motion were needed. Galileo knew that forces caused material objects to move. He could describe the common motions of objects quite accurately and he knew how the natural force of gravity made objects near the earth fall toward the earth, but that was all that he knew. He could not and did not properly define a physical quantity (mass) to describe matter or the amount of matter in an object, so Galileo could not develop a complete theory of motion. Galileo did define **inertia** as 'a tendency of an object to remain at rest or in motion unless an external force acts on it,' but this description of inertia is not complete by today's standards. So Galileo did not develop the theory of motion as we understand it today. Galileo got pieces of the puzzle, such as free fall, compound motion, the concept of relative motion of objects, and the acceleration due to gravity, but he could not see the whole picture. Yet Galileo prepared the way and set the stage for the later development of a true and accurate theory of motion by Newton.

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Writing Assignment: Complete the 'Activities' on pages 30 and 39. Write a report about your results, making it as complete as possible, and send a copy of your report to the instructor via email. The report is due by Friday by the end of week 1.

Discuss the various 'Questions for Thought' at the end of the chapter and submit your written responses to the instructor via email. The best of the responses will be posted on the Internet for the whole class to read and comment upon as threaded questions and sources for further discussion. Your participation will be graded.

Complete the 'Parallel Exercises' on pages 45 and 46. Group A solutions and answers are given in the back of the book. Group A problems are for practice. Submit the answers (only) to the Group B problems to the instructor by Friday at the end of week 1.

Lecture 3:
Patterns of Motion

Once the basic concepts of speed, momentum, force and acceleration were defined, even in the event that the initial definitions were not completely accurate, it became the task of science to relate all of these quantities in a single theoretical model. It fell to Isaac Newton to discover the correct theory of motion and he did not inform the rest of the world about his theory until 1687. In that year, Newton published his book the *Principia* (the *Mathematical Principles of Natural Philosophy*), which completely described the general theory of motion in much the same form as we study it today.

Newton’s first task was to define mass correctly and relate it to inertia. Since inertia was basically a resistance to a change in a material object's state of rest or motion (according to Galileo), Newton noted that **mass** and inertia were proportional to each other. He reasoned that mass not only represented the "amount of matter" in a body but could also be measured by the resistance of that body to a change in its state of motion.

From this basis, he derived three interdependent laws of motion. These laws of motion form a single interrelated whole, a set of rules each of which depends on the others.

Newton's **first law of motion** stated that [1] ***An object will remain at rest or traveling along a straight line if it is already moving unless an external force acts on it***. Within this statement, straight-line motion was specifically designated as the natural motion followed by all material objects in Newton's model. This represented a distinct change form the Aristotelian point of view that held that circular motion was natural for all bodies from the moon's orbit and outwards, while natural motion was toward the center of the earth below the moon's orbit. Newton's new law followed directly from Galileo's definition for the inertia of a body. Newton only added the necessary requirement that the natural state of motion was a straight line, which was original with Newton. To learn more about the laws of motion, go to www-istp.gsfc.nasa.gov/stargaze/Snewton.htm or www.grc.nasa.gov/WWW/K-12/airplane/newton.html .

Then, Newton's **second law of motion** became a necessary consequence of his first law: [2] ***An applied external force causes a change in any object's momentum***. However, Newton's original statement of this law was eventually interpreted in the slightly different form of F = ma (or a =F/m), which is the form by which we understand the law today. This new form can be interpreted as stating that a force (F) applied to an object with mass (m) will cause it to accelerate (a) proportionally. The unit of force is the **Newton**, named in honor of Isaac Newton. When more than one force acts on a single object, the resultant of the forces, or the net force causes a proportional acceleration. This law gave science a method of measuring the mass or inertia of an object for the first time, relative to its changing state of motion. If the applied force and resulting acceleration could be measured, then the mass would essentially be measured. In this case, the mass would be called the inertial mass since its value or magnitude was derived by inertial methods.

Another application of this formula relates the weight of an object to its mass, or amount of matter, such that $F_{weight} = mg$. This relationship gives us a way to weigh objects and obtain their masses. Since g is very nearly constant over the surface of the earth, we get $m = F_{weight}/g$. In essence, two kinds of mass are represented in these relationships; inertial mass and gravitational mass, but they are considered equivalent in all cases. In other words, we could say that mass, or the amount of matter in an object, responds to normal accelerations in exactly the same manner as it responds to gravitational accelerations.

Newton first stated his second law in terms of **momentum**, not acceleration as is commonly thought today. Momentum is the simplest physical expression that completely represents the motion of matter in the form of a single quantity. Momentum is equal to the product of an object's mass (representing the matter in the object) and its speed or velocity (representing the object's motion). Yet, in its momentum form, Newton's second law is equivalent to the form F = ma. Since a force causes a change in momentum, we could say that force equals a change in momentum occurring over a period of time, but momentum is mv. Now a change in momentum would not affect or change an object's mass, so the changing momentum must result solely from a change in the object's speed.

F = change in (mv)/change in time = m [change in v/change in time] = ma

This would change Newton's original second law to the recognized form of the force equaling the constant mass times a changing speed over a changing time, which is just the definition of acceleration. So Newton's original statement was mathematically equivalent to the later interpretation of the second law as F = ma.

However, Newton's original form of the second law still yields new information and other possibilities for application to physical phenomena that the newer form cannot render because it refers to momentum rather than acceleration. For example, suppose that two objects collide, head on, each with its own initial momentum. Since a force causes a change in momentum, the opposite is true in that a changing momentum can result in a force. When the two objects collide, each object causes a force on the other due to their changing momentums during the course of the collision. So each object applies a force on the other, and they bounce off of each other. Further assuming that the two objects are highly elastic and exhibit perfect bounce, each changes the momentum of the other proportional to their exerted force on the other during the collision and thus the total momentum of the two combined remains constant before, during and after the collision. The two objects have just swapped their motions, as represented by their momentums, taking into account the differences in their masses. This idea is called the **conservation of momentum** and is a general principle of the physical world around us. Literally, each colliding object causes a force or change of momentum equal to its own initial momentum, and the total amount of momentum (or material motion) for the complete collision system remains constant because the colliding bodies just swap momentums through the force of their collision.

This notion of swapping forces brings us to Newton's **third law of motion**, which can be stated as follows: [3] ***for every action there is an equal and opposite reaction***. Take for instance a book resting motionlessly on a table. We know that the force of gravity is pulling the book downward due to the weight of the book, but the book doesn't move. Therefore, the table must be exerting an equal and opposite upward force on the book so the net force on the book is zero, and the book remains at rest. From the physics point-of-view, the book on the table is no different than a tug-of-war between two teams when the teams are pulling on the rope in opposite directions with equal force and neither team is moving the other. The first two laws of motion necessitate the third law so that this and similar situations can be explained within the general theory of motion. And yet more can be derived from Newton's laws of motion.

Until the seventeenth century, Aristotle and nearly everyone else thought that the moon, planets and stars moved around the earth in circular orbits. Circular orbits were so well ensconced as a primary fact in science that Galileo believed in circular orbits, even though he believed that the earth and all the planets orbited the sun rather than everything orbiting the earth in circles, as most others believed. Below the orbit of the moon, natural motion was straight down toward the center of the earth. So the physics of heaven and earth were separate. Even the basic elements were different for heaven and earth. The earth was composed four primary elements, earth, air, fire and water, while the heavens were composed of the perfect element, aether. But Newton made no such distinction, and thus derived a single physics for the entire universe, the earth and heavens combined. According to Newton's first law, a moving object, such as the moon, must follow its natural course along a straight line (not an Aristotelian circle) and if it did not then an external force must act on it. When the deviation from a straight line is constant, as in the case of perfect circular motion, then the deviating force must also be constant. So, the fact that the moon and the planets did not travel in straight lines meant that some external force must cause them to deviate in a regular and discernible pattern. Newton reasoned that the unidentified force must be gravity.

The moon's orbit, and other orbits in general, are not circular but rather elliptical, a fact which was discovered by Johannes Kepler in the late sixteenth century. Kepler successfully described the orbits of the planets around the sun, but could not account for the forces that drove the planets around the sun and the moon around the earth. But Newton's laws of motion implied that gravity was the culprit. Since the moon's orbit around the earth is very nearly circular, Newton could assume circular motion as an approximation for the purposes of making calculations.

Circular motion is a very special case since the deviating force is constant and the speed of the circling or orbiting object is also constant. At any given moment, the object would want to go off on a straight line away from the circle, but the force moves the object toward the center or midpoint of the circular motion. So a centripetal, center-seeking, acceleration results. This centripetal acceleration is equal to the square of the speed divided by the radius of the circular motion ($a_{centripetal} = v^2/r$). The centripetal acceleration is not due to a change in speed as was our other notion of acceleration, but is due purely to a change in direction of the moving or, in this case, orbiting object. The force that keeps the object in its orbit around the center is classified as a **centripetal force** and is equal, according to Newton's second law, to the product of the object's mass and the centripetal acceleration, so $F_{centripetal} = mv^2/r$. An animated example of centripetal force can be found at www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/cf.html .

In the case of the moon or other satellites orbiting the earth, gravity supplies the centripetal force, or rather; gravity acts centripetally, pulling the moon or satellite into its earth orbit, against the tendency of the satellite to go off in a straight line according to Newton's first law of motion. On the other hand, a ball at the end of a string is pulled toward the center of its own circular path by the force of tension in the string. The force of tension is a product of a person's pull on one end of the string at the center of the circular motion and the ball's natural tendency to move away from the circular path along a straight line at the ball's end of the string. The force of tension in the string merely transmits the person's pull to the circling ball. But gravity was the key to the universe for Newton, so he needed to derive the proper model to describe how gravity works.

Gravity is always an attractive force between material objects. Since Newton had defined mass, not just as the "amount of matter" in an object, but by its relationship to inertia, he could further say that any gravitational force between two objects would depend upon their masses. In particular, gravity is proportional to the product of the two masses that are equally or mutually attracting each other. It was already known that gravity decreased with distance, or more precisely, gravitational force varies as the inverse square of the distance ($1/r^2$). Putting these notions together, Newton assumed that $F_{gravity}$ was proportional to Mm/r^2, a mathematical relationship that could be reduced to equality if the proper constant of proportionality were chosen. So, Newton's **universal law of gravitation** became

$$F = G\ Mm/r^2$$

where G is the universal constant of gravitation and has a value of $6.67 \times 10^{-11}\ Nm^2/kg^2$; M is the mass of the larger object in kilograms; m is the mass of the smaller object in kilograms; and, r is the distance between the centers of the two objects in meters. Some examples of this law are given at astronomica.org/textbook/equations/2_NULoG.html .

Since the weight of an object is caused by the gravitational attraction between that object and the earth, the force of weight (=mg) and the gravitational force are equal, such that,

$$F_{weight} = F_{gravity}$$
$$mg = G\ Mm/r^2$$
$$g = GM/r^2 \text{ , and thus}$$
$$G = gr^2/M\ .$$

This derived relationship allowed Newton to calculate the value for the universal gravitational constant since he had already measured the acceleration due to gravity, g, he knew the radius of the earth r and the mass of the earth M. Newton could not measure G directly, so he calculated G in this manner and came up with a value quite close to the above-accepted value of today.

Next, Newton needed to prove his new relationship for the force of gravity. He used the fact that the moon's orbit around the earth is very nearly circular and the force of gravity held the moon in its orbit to predict the speed of the moon. He set the formula for a centripetal force equal to his new formulation for gravity, such that

$$F_{centripetal} = F_{gravity}$$
$$mv^2/r = GMm/r^2$$
$$\text{so}\quad v^2 = GM/r\ ,$$

where M is the earth's mass for any material object orbiting the earth. Placing the distance from the earth to the moon into the formula for r, Newton thus calculated a value for the speed of the moon around the earth based completely upon his theory. However, the speed of the moon around the earth can be calculated quite easily and directly from straightforward observation. Newton's value of the speed from his theory matched that from observation, so his theory was proven. In essence, Newton's theory predicted a speed of the moon around the earth that was confirmed by direct observation. Of course, there were many other proofs of Newton's theory, but his prediction of the moon's speed was significant for many scholars in his day. It was also rather significant and important that Newton's gravitational theory explained many other physical phenomena such as the earth's tides and the precise time of the return of Haley's comet. So, Newton's theory of motion and gravitation became the cornerstone of physical science, the model of development for all other sciences to follow, and an important factor in the continuing evolution of human society.

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Writing assignment: Complete the 'Activities' on pages 50 and 53. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 2.

Complete all of the 'Questions for Thought' in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 2.

Complete the Group A and Group B exercises on pages 65 and 66. Send the answers to the Group B exercises to the instructor via email. Your answers are due by the end of week 2.

Lecture 4:
Energy

Newtonian mechanics, as the application of Newton's theory to the real world is commonly called, became so successful during the eighteenth century that it affected all areas of science, culture and civilization. This same century saw the rise of industry and manufacturing, which were also influenced by the new worldview represented by Newtonian mechanics and the subsequent changes in science, and with them emerged an economic interest in the scientific concepts of work, energy and power. In other words, the industrialization of the eighteenth century acted to spur on the further development of Newtonian mechanics.

During this time period, the first development of steam engines necessitated the definition of work and power within Newtonian physics. Within this context, **work** became the product of a force that was applied to move a material object through a measurable distance. Therefore,

$$\text{Work} = F \cdot d$$

In the physical sense, if an object has not been moved then no work has been completed. This stipulation was completely necessary to guarantee the physical consistency of the concept.

For example, if you lift a one-kilogram mass to a height of one meter, you have done work. That work is equal to force needed to overcome the weight of the object, or

$$\begin{aligned} mg &= 1 \text{ kg } (9.8\text{sec}^2) \\ &= 9.8 \text{ kg}\cdot\text{m/sec}^2 \\ &= 9.8 \text{ Newtons ,} \end{aligned}$$

times the distance of 1 meter that the object was lifted.

$$\begin{aligned} \text{Work} &= 9.8 \text{ N}\cdot 1\text{m} \\ &= 9.8 \text{ N}\cdot\text{m} \\ &= 9.8 \text{ Joules.} \end{aligned}$$

The **Joule** is the unit of work in the SI and metric systems.

If you then hold the one-kilogram mass at arms length without letting it fall your arm gets very tired because you are counteracting the gravitational force that wants to pull the mass down, BUT YOU ARE NOT DOING ANY WORK because the mass is not moving through any distance. No matter how tired your arm gets, you are not doing any work in the physical and scientific sense. Think of it this way: If you DID do work holding the mass at that level position, then a table would do the same amount of work if you placed the mass on the table at the same height above the ground, and it would be complete nonsense to think that the table could do work under such circumstances.

On the other hand, the concept of work implies another physical quantity of equal import; **power**. Whether you lifted the one-kilogram mass quickly or slowly, you would still be completing the same amount of work because the mass ended up at the same position one meter above the ground, but the two actions are not physically the same. The difference between the two cases comes from the amount of time that it took to lift the mass, not from the work done. It takes more power to lift the object quickly, and less power to lift it slowly. So power = work/time, or P = W/t. The common unit of power is called the **Watt**, but the English unit is also used quite frequently and it has a more interesting story behind it.

In the early part of the Industrial Revolution, the primary source of power was the horse. Horses were used for pulling wagons, various loads of materials, plows and many other similar tasks, so one bright scientist set out to discover the average power that a large English plow horse could develop. The best horses could pull a sled with about 550 pounds of weight on it a speed of about 1 foot/second. So, the value of 550 lb-ft/sec or ft-lb/sec became the standard unit of measurement in the English system, more commonly referred to as one **horsepower**. Cars in America and England commonly use the horsepower as a measure of the engine's power output, but Europeans and other nationalities always measure engine power in Watts.

Picturing a weight lifter at the Olympic games would make a better example of power. The weight lifter attempts to lift a 200-kilogram mass, which would have a weight of 1960 Newtons, above his head. The trick is to bend at the knees and lift the mass off of the ground using the strength (and power) in your legs. Then, with the weight hanging at the bottom of your arms extended downward, jerk the weight up to your chest and push it straight up above your head as fast as you can. This is called power lifting. If a weight lifter completes the movement correctly, he or she will succeed, but if the weight lifter slows down, he or she will fail. The mass is lifted quickly as a measure of the maximum power that the weight lifter can muster, which is a measure of the strength of the individual. Since power, in physics, is work/time, a shorter time in the denominator of the ratio will mean that more power is exerted to lift the mass. Thus we have the name, power lifting.

The weight lifter completes the same amount of work, whether he or she lifts quickly or slowly, but the stronger person develops a quick burst of **energy** and lifts the weight quickly, utilizing and thus measuring the person's overall strength. Therefore, the work done is also equal to the energy produced to accomplish the task, implying that there is still more to the concept of work than just the new concept of power.

If you lift an object through some height, then you are giving the object (gravitational) **potential energy** equal to the energy that you have used to lift the object. Since you have applied a force to counteract the weight (mg) of the object to lift it through a distance (h for height), then the work done is equal to the quantity mgh, which we define as potential energy (gravitational). Potential energy actually means the ability to do work, or can refer to different types of stored energy. Gravitational potential energy is many times referred to as mechanical potential energy or just potential energy. Now, the object is at a height h and if you take your hand away, the object begins to fall as the force of gravity does work on the object to move it back down through the height h, imparting to the object a **kinetic energy**. Kinetic energy, which is the energy of motion, therefore depends upon the object's speed v. Kinetic energy is a product of the mass of the object and its speed, such that K.E. = ½ mv^2. Kinetic energy is related to momentum, in that it is a higher order of 'matter in motion.' Both quantities are simple and fundamental representations of 'matter in motion' and thus hold a special place in physics.

The special place in physics and science that the different forms of energy hold is best illustrated in the following example. Try this yourself exercise yourself. Place you hand flat on a table with your palm up. Put a coin in your palm. Now lift the coin to a height of ½ meter above the tabletop. At this position, the energy that you used to lift the coin has been converted to potential energy in the coin. Now repeat the process, but instead put more energy into lifting the coin and make it rise up faster, but stop your hand at the ½ meter position once again. In this case, the coin continues to rise above your hand when your hand stops. How far it rises depends on how much extra work or energy you put into the system. You actually did enough work, or put enough energy into the system to give the coin both the same potential energy as well as some kinetic energy. This situation and many similar situations can be described by a relationship called the work-energy theorem, or

Work = change in potential energy + change in kinetic energy.

This relationship is extremely important because it leads us to a more comprehensive relationship that is called the **conservation of energy**. Examples of this principle can be found at www.homeworkhelp.com/homeworkhelp/freemember/text/phys/high/demo2/main.htm

and solomon.physics.sc.edu/~tedeschi/demo/demo18.html .

The amount of work that you completed is equal to the amount of energy it took to lift and propel the coin upward. The amount of energy that you used was transferred completely to the coin as potential and kinetic energies, so the total energy of the system would equal the work done and it would be constant (neglecting air resistance as in the ideal case). No matter where the coin is during its motion, its combined PE and KE would be equal to the energy put into the system by the work in the beginning. In other words, energy is conserved in this action. The conservation of energy is a general principle of nature as defined in physics, making it perhaps the strongest of all the relationships in nature.

These two basic forms of energy, potential and kinetic, are the most fundamental of all the known energies. Or, at the most basic level of physical reality all other forms of energy reduce to either potential or kinetic. In this sense, potential energy is the energy of relative position and kinetic energy is the energy of relative motion. Yet in most cases, it is more convenient to describe energy in other terms. For example, we have chemical energies, heat, electrical energy and nuclear energies. Under the proper circumstances, these various energies are useful in our common world and are worthy of study in their own rights. These forms of energy come from many different sources. Ultimately, all of our energy on the earth came from the sun. Living organisms utilize energy from the sun in different ways. Plants use the energy in sunlight to create glucose through a process called photosynthesis, while animals eat plants and metabolize the glucose to create energy for use in their muscles. Animals give off carbon dioxide as a waste product during metabolization of glucose and plants take up that carbon dioxide in photosynthesis to create oxygen for animals to breathe. Plants and animals are thus symbiotic forms of life with regard to their utilization of basic energies.

When the plants die, they can undergo bacterial degradation and turn to methane gas and other byproducts. However, in some extreme cases, the plants in swamps and marshes died and were buried underneath the earth many millions of years ago. Under the action of heat and pressure, these plants ultimately became the coal that humans use for energy. On the other hand, millions of years ago microscopic sea animals died and were also buried deep underground. These dead animals decayed under the processes of heat and pressure and became oil and gas deposits which are also mined for our use as energy. Together, the coal, oil and gas that we mine are called **fossil fuels**, and with radioactive materials that we mine from the earth for use as nuclear energy, they form the major sources of energy that we use in our everyday lives. Also see www-formal.stanford.edu/jmc/progress/firstlaw.html .

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Writing assignment: Complete the 'Activities' on page 85. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 2.

Complete all of the ‘Questions for Thought’ on page 87 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 2.

Complete the Group A and Group B exercises on pages 87 and 88. Send the answers to the Group B exercises to the instructor via email. Your answers are due by the end of week 2.

Lecture 5:
Heat and Thermodynamics

Continuing the line of progression from the founding of Newton's laws of motion, the next hurdle, heat, came to the forefront of scientific inquiry in the early nineteenth century. Heat was originally thought to be a massless fluid, called caloric, that existed within material bodies. Caloric was thought massless because careful measurments showed that heating an object did not change its mass or weight. Today, we still use the **calorie** as the unit of heat and retain some of the simple rules for heat exchange from the older theory, such as heat always travels from a hotter to a colder body, never the reverse. But the caloric theory failed as science became more accurate and sophisticated in its explanations of nature. The caloric theory was replaced by a new theory based upon the motions of individual **molecules** in the smallest portions of a material body. The **kinetic theory of matter**, as this theory was called, eventually evolved into a whole branch of science within physics called thermodynamics, a name which relates **heat** (thermo) to the study of the forces which cause matter to move (dynamics). A good source for information on the Kinetic theory of matter can be found at www.apsu.edu/robertsonr/nova/Matter%20and%20Kinetic%20Theory%20Notes.htm and homepages.westminster.org.uk/Ken.Zetie/fifth/MATTER1.html .

It was discovered early in the Industrial Revolution that heat could be converted to mechancial motion. That simple idea is the basic principle behind all engines just as it became the basis of all later improvements in the original steam engines. But by the beginning of the nineteenth century, the reverse idea that motion itself could cause heat was also discovered. Simple experiments like rubbing one's hands together to warm them, or placing ice between two sticks at a constant temperature below ice's melting point and causing the ice to melt merely by rubbing the ice between the sticks, proved to many scientists that heat depended upon motion and not an artificially invented substance such as the caloric theory proposed. From such humble beginnings, the kinetic theory rose to become an integral and important branch of science, but first the difference between the concepts of heat and **temperature** needed to be settled and that could not be accomplished until a standard of measuring temperature was found.

Three common thermometers are in use today. The first thermometer developed to measure temperature, the **Fahrenheit scale,** is based upon the melting point (32 degrees) and the boiling point (212 degrees) of water. There are 180 degrees or temperture units between these two poiints. The next thermometer is alternately called the **Celsius scale**, after its inventor, or the centigrade scale because there are 100 units between the melting and boiling points of water upon which this scale is also based. These facts mean that Fahrenheit degrees are 5/9 (or 100/180) as large as Centigrade degrees, leading to the formulas for converting temperature on one scale to the other. The temperature in Fahrenheit degrees is equal to 5/9 times the Centigrade temperature plus 32 degrees while a Centigrade temperature equals the Centigrade temperature minus 32 degrees with the result multiplied by 9/5. Another more efficient scale is also used, the **absolute or Kelvin scale**. The Kelvin scale is not based upon a random physical fact such as the melting and boiling points of water, but is instead based upon the temperature at which all molecule vibrations and random motions cease for all material substances, called **absolute zero**. Thus the name absolute scale. It does not depend upon random circumstantial facts. The units of the Kelvin scale, appropriately called Kelvins rather than degrees, are the same size as Centigrade degrees. Since absolute zero, the point at which all external molecular motion ceases, is 273 degrees below zero on the Centigrade scale, ice melts at 273 Kelvins and water boils at 373 Kelvins. In many cases, any calculations in physics must use the absolute scale with Kelvin units for problems to work out correctly. The Kelvin scale was not developed until after thermodynamics was established as a branch of physics, so it played no role in the early development of the kinetic theory of heat. It was a result of that theory.

As the kinetic theory developed, it became evident that there were conceptual differences between heat and temperature. In the final analysis, the amount of heat in an object is related to the total kinetic energy of the individual material molecules of which that object is composed. On the other hand, temperature is related to the average kinetic energy of the individual molecules. A material object is composed of a very large number of molecules, so to find the heat in an object you would need to find the average kinetic energy of the individual molecules (which are related to temperature measured in Kelvins) and multiply that number by total number of molecules in the object. So, heat and temperature are related concepts, but still quite different.

Different objects, made of different substances, will hold different amounts of heat, depending upon their molecular construction. It would be difficult if not impossible to explain how molecular structure affects the amount of heat in an object at this level of study, but we can still gain a simple notion of how different objects hold heat. The positions of the molecules in a solid object are fixed about specific points within the solid. As a solid gets warmer, the molecules will vibrate about that equilibrium position. The hotter the object gets, the greater the kinetic energy of the individual molecules and the greater that they vibrate about their fixed equilibrium positions. Since each substance from which an object can be composed has a different internal molecular structure, different substances have different specific heats. The **specific heat** is a measure of how much heat or vibrational energy the molecules of a substance can absorb and store. The standard used for measuring specific heat is liquid water. In its solid state, ice, the specific heat is about one-half calorie/gram-Centigrade degree. This means that ice can absorb one calorie of heat for each gram and centigrade degree that the temperature increases. For liquid water the value is one cal/gram-Centigrade degree, by definition, and for steam, the gaseous state of water, the value is again about one-half. Although the internal molecular structure of water is the same in each case, the external structure holding the molecules together to make ice, liquid water and steam are different, so the specific heats in each of the three states or phases of a substance are different.

The specific heat of a substance is related to the total quantity of heat that can be absorbed by that substance. Otherwise, the quantity of heat is related to the mass of the substance and the temperature of the object. So we can calculate the amount of heat that it takes to change water from one temperature to another by utilizing the formula Q = mc(change in temperature), where Q stands for the quantity of heat in calories, m is the mass of the object, and c is the specific heat of the substance of which the object is composed. For example, the quantity of heat needed to change 100 grams of water from 0 degrees to 100 degrees Celsius would be (100grams)(1 calorie/gram-Centigrade degree)(100 degrees centigrade) or 10,000 calories. In this manner, we can gain some knowledge of how temperature and heat are related within a single object as the object changes temperature. When heat is transferred from one object to another, the same relationships are used, but one last factor must be taken into account. In particular, the heat lost by one object is equal to the heat gained by the other. This fact is a simple statement of the conservation applied to the exchange of heat energy alone.

Matter comes in three different states or phases; solid, liquid and gas. Solids have fixed shapes and constant volumes because the molecules or atoms of which they are composed are centered about fixed positions. Liquids have constant volumes, but their shapes are not fixed so they take the shape of their containers. In liquids, the electrical forces that bind the molecules to each other are loosened a little from the solid phase, so the molecules are able to slide past each other but remain in close proximity to each other. This allows the liquid to take the shape of its container. On the other hand, gases have no fixed volumes, but they still take the shape of their containers. In gases, the molecular forces that hold the molecules together have been totally broken and the molecules bounce around randomly due to their higher individual kinetic energies. The hotter the gas, the more it expands in volume unless it is in a rigid container, and then the volume remains constant but the gas pressure on the inside of the container increases. Volume and pressure on a container are approximately constant for solids and liquids across the whole range of temnperatures at which they exist. It is in this manner that the kinetic theory explains the structure of material objects and the phase changes or changes of state that bodies of matter can undergo at different temperatures.

Between each of these phases, the absorption and retention of heat energy acts differently than in the case of increasing heat within a single phase. For example, very cold ice gains temperature as it absorbs heat until the temperature of the ice reaches the melting point of 0 degrees Centigrade. At that point, more heat only goes to melting the ice without increasing temperature. In fact, the temperature remains the same until all the ice has melted into liquid water. When the mass has become liquid, and only then, will added heat increase the temperature. The same is true when liquid water at 100 degrees Centigrade changes phase to steam at the same temperature. Water at 0 degrees has far more internal energy than ice at the same temperature. The amount of heat needed to cause the ice-water transition is called the **latent heat of fusion**. Steam at 100 degrees has far more energy than water at the same temperature because the excess energy has gone into breaking the electrical bonds which hold the molecules close together to form liquid water. The amount of heat which causes the **phase change** from liquid water to steam is called the **latent heat of vaporization**. It takes more heat to cause a phase change (upward) then it takes to change the temperature within a phase. So steam has a great deal more internal energy than water at the same temperature of 100 degrees, and steam burns are far more painful then water burns. Since there is no temperature change during phase changes, the quantity of heat needed to accomplish a phase change is just equal to the mass of the object times the heat of fusion for transitions between the solid and liquid phases and the product of the mass of an object and the latent heat of vaporization for a transition between the liquid and gaseous phases of a substance. Some phase changes occur naturally in the world around us. A gas spontaneously changes to a liquid in a process called condensation (which occurs when it rains), a liquid spontaneously changes to a gas in evaporation (which suppies moisture to the air tocause rain) and a solid goes directly to a gas in the process of sublimation.

Heat energy can be transferred from object to object or within a single object or a group of objects by three different methods. Heat can move through an object, a process called **conduction**. Heat is a function of the vibrational energy of individual molecules. One molecule in an object vibrates quicker with increased heat and thus hits it neighbors more often, transferring energy or heat from molecule to molecule. So heat is conducted through a material body by molecules bouncing off of one another with more and more added heat, transferring energy throughout the volume of the object. But heat can also be transferred or transmitted by **convection**. In convection a whole body of a substance moves and carries its heat to another body. A good example of this is the convection currents from a heater within a room, or even the warm winds that blow on a hot summer's day. And finally, heat can be transferred by **radiation**, in particular, by heat rays. Heat rays are actually normal light in the red and infrared range of energy. Those particular colors of light are more efficient at transferring their energy to other physical objects, so they have traditionally been called heat rays. These rays are the part of sunlight which feels hot on your skin when you stand outside in the bright sun. In the case or heat transfer by radiation, no intervening matter is necessary for the heat transfer as is the case in both conduction and convection. These light rays carry heat from the sun to the earth across the vast emptiness of outer space between the sun and earth.

The kinetic theory of matter, as the above theory of heat and temperature is usually known, is only a part of the science of thermodynamics, which is far more precise in its principles. Thermodynamics was born in the 1840s when James Joule melted ice in a thermally insulated container by the mechanical action of a small paddle wheel. In other words, Joule succssfully changed Joules of mechancial energy to calories of heat energy inside the insulated container and established the fact that 4.18 Joules of mechanical energy are equal to 1 calorie of heat energy. For this reason, the mechancial unit of heat was named after Joule and his experiment marks the birth of a whole new science within physics. But thermodynamics is far more than just a simple elaboration of the kinetic theory of matter. Thermodynamics more closely relates heat to the concept of work and establishes important methods of dealing with the intimate relationships between these two forms of energy.

The physical quantity of the greatest importance in thermodynamics is the **internal energy** of an object. Newtonian mechanics normally deals with the **external energy** of a material body as it is affected by an external force. In this manner, thermodynamics differs from normal Newtonian mechanics, but still uses Newton's laws of motion at the molecular level to explain heat and temperature. According to the **first law of thermodynamics**, the internal energy of an object is a function of both the heat of the object and either the work done on the object by an outside source or the work done on the outside environment by the object. So, a change in the internal energy can come from either the addition or subtraction of heat and the work done on the system or by the system on the environment. In other words, the vibrational energy of molecules that is related to the temperature of an object or an isolated system, can be changed by either heat processes or the mechanical processes of work. Alwso look at www.cchem.berkeley.edu/~chem130a/sauer/outline/firstlaw.html for more on the first law. This particular relationship is ideal for the explanation of **heat engines**, which are mechancial devices that change heat energy to mechancial energy, such as steam engines and internal combustion engines. In fact, the science of thermodynamics was instrumental in the developemnt of both the gasoline powered internal combustion engine and the diesel engine. When the relationship is turned around, the first law of thermodynamics leads directly to refrigeration systems, which were origianlly developed from purely thermodynmical considerations.

In a heat engine, such as a gasoline engine, there is a high temperature reservoir of internal energy, such as that produced by the exploding gasoline-air mixture in the engine's cylinders. That energy is channeled or directed toward two different ends, doing work as in moving the car forward and energy lost to the surrouunding environment as in the gases exhausted through the car's tailpipe. This process is explained quite well by a combination of the first law of thermodynamics and the **second law of thermodynamics**. According to the second law, at least in its simplest configuration, heat dissipates naturally or energy always moves from the hotter to the cooler object. The engine runs at a higher temperature than its surroundings and the heat must dissipate according to the second law. It dissipates heat by either doing work or heat loss to the environment as exhaust in the manner prescribed by the first law. more on the second law can be found at hyperphysics.phy-astr.gsu.edu/hbase/thermo/seclaw.html .

The second law can also be stated by invoking a concept called **entropy**. Entropy is a measure of the disorder of a system. According to the second law any system naturally increases in entropy, or rather, systems naturally tend to become more disorderly. Therefore, entropy is a statistical quantity and the mathematics of probability theory has been introduced into physics. This increase is often called time's arrow because it is the only rule in physics which stipulates a difference between time moving forward and backward. Since entropy always increases, time always goes forward. A good example of entropy can be found in an explanation of how a perfume scent spreads out through a room. A closed bottle of perfume is set on a table. It represents a more orderly state becasue all of the molecules of the perfume can be located within the confines of the bottle. Then the cap is removed from the bottle. The perfume molecules slowly dissipate throughout the room, which represents a more disorderly state because the molecules can only be located somewhere within the much larger room. The perfume dissipates throughout the room just as heat naturally dissipates throughout space. The perfume molecules will never return from throughout the room into the bottle, at least not naturally, because such an event would represent moving from a less orderly to a more orderly state and violate the second law of thermodynamics. So, one would think that taking energy out of a colder environement and placing it in a warmer environment as is done by a refrigerator is a direct violation of the second law, but that is not true.

In a refrigerator, work is done by a volume of gas or some other material body on its environement which removes internal energy from the system or object, but the body of gas is thermally insulated from the environment so there is no heat exchange between the body and the outside world. Since there is no heat exchange even though internal energy was lost due to the work done by the body, the internal energy decreses with a corresponding drop in temperature. In a common refrigerator, internal energy is removed from the molecules of air inside a thermally insulated box by work done by the cool air mass. This process is accomplished by evaporating a special substance passing in tubes through the cooler air mass in the insulated box. The evaporated gas is pumped out of the tubes in the insulated box carrying the internal energy gained from the cooler air, where it releases that energy into the environment and condenses only to be pumped back into the tubes in the insulated box and capture more internal energy from the still cooler air mass.

In effect, energy has been transmitted from a cooler body to the warmer environment without violating the laws of thermodynamics. The feasibility of this process was actually predicted by the laws of thermodynamics which made refrigeration possible. Building a working refrigeration system then became an engineering problem and was quickly accomplished. From the standpoint of entropy or the state of order within the system, if you consider the inside of a refrigerator alone, the entropy has decreased which would seem impossible, but when the complete system including the outside environment is considered, the gain in entropy of the environement far outweighs the loss inside the refrigerator, so there has been a net increase in entropy and the second law is saved.

So, both internal combustion engines and refrigerators emerged from the latest succeses of Newtonian physics. Thermodynamics was a direct outgrowth of the Newtonian laws of motion. However, it would be impossible to know the motions of each and every molecule in a system or object, so statistical methods were used for the first time in physics to describe macroscopic effects (heat and temperature) by analyzing microscopic phenomena (the vibrations and motions of molecules and atoms). These new methods were instrumental in the development of a new revolution in physics at the beginning of the twentieth century.

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Writing assignment: Complete the 'Activities' on page 102. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 3.

Complete all of the ‘Questions for Thought’ on pages 117 and 118 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 3.

Complete the Group A and Group B exercises on pages 118. Send the answers to the Group B exercises to the instructor via email. Your answers are due by the end of week 3.

Lecture 6:
Wave Motions and Sound

The heat in an object is due to the vibrational motion of the molecules that compose the object, but these vibrations and motions are irregular and erratic. A far more interesting case comes from the regular and periodic vibrations and motions of matter. Such motions are called periodic because they repeat themselves after a specific and definable period of time. In fact, a major characteristic of all periodic motions, and there are many different types, is the fact that they have specified periods and frequencies. A **period** (designated T) would have the simple units of time, but a **frequency** (designated f) is literally how frequently the motion repeats itself, so a frequency would have the units of repetitions/time such as a cycle/second (also called a **Hertz**) or a revolution/minute. A complete repetition of the motion is often called a single **cycle**. The period and frequency of such motions are reciprocals of each other such that $T = 1/f$. An amplitude that measures the distance of successive portions of the vibration from the equilibrium or central position of the vibration also characterizes these motions and follows the rule the greater the amplitude, the greater the energy of the vibration.

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Periodic motions are also called harmonic motions, which implies, quite correctly, a relationship to music and sound. The most commonly studied motion of this type would be a simple harmonic motion or SHM, which is actually the scientific name for a periodic vibration. Studying a SHM offers a basis for the study of all periodic motions. There are commonly three general classifications of periodic motions; Orbits of circular motions and other shapes repeat themselves and have regular periods, such as the period of the earth around the sun is a little more than 365 days; Regular vibrations which are studied by using the example of a mass at the end of an spring; And, the pendulum swinging back and forth in a gravitational field.

Vibrating material objects cause disturbances in the media (such as air) around them. When these vibrations are regular with definable periods and frequencies, such as is the case in SHM, and then the disturbances that they cause have similar periodicity. For example, when the head of a drum is struck, it vibrates at a specific frequency. As it pushes upward, it compresses the air above it, and when it vibrates downward, it rarefies the air above it. The drumhead vibrates upward again compressing the air and pushing the previous areas of compression and rarefaction away. Such an alternating combination of **compression** (or **condensation**) areas and **rarefaction** areas in a medium such as air, traveling away from the source of the production, would be called a sound wave.

Such a sound wave would be characterized by the same period and frequency as its source as well as a specific speed of travel, called the wave speed or velocity, which depends on the physical characteristics of the medium, air, through which the wave travels. In general, waves travel faster through denser media, and slower through less dense media. So sound travels faster through steel than water, and faster through water than air. Since empty space, a vacuum, has zero density, sound will not even travel through a vacuum like outer space. The speed of a wave also depends upon the condition of the medium through which it travels, so a sound wave moves at different speeds through the same air depending upon water and dust content in the air as well as the temperature of the air. At the freezing point, sound travels at 331 meters/second or 1087 feet/second. For each Centigrade degree above freezing, the speed of sound increases by 0.6 meter/second, or for each Fahrenheit degree above freezing the speed of sound increases by 2 feet/second. Warmer air transmits the sound waves more rapidly because the air molecules are more agitated with more internal energy, so they come into contact more often and pass the energy of the wave along more rapidly.

A specific length that extends from an area of compression to the next alternating area of compression can further characterize a wave. This length is called the wavelength (designated by the Greek letter lambda), and the speed of the wave is a product of the frequency and wavelength, such that

$$v = f\ (\text{lambda}).$$

This formula is called the wave equation and acts to define the wave. It is equivalent to the definition of speed or velocity for normally moving matter in the Newton theory of motion. In all cases and for all waves the speed is defined in the same manner. In general, there are two primary types of waves whose difference depends upon the relationship between the direction of the vibration of which the wave is constructed and the direction that the wave is traveling. If the vibrational disturbance in the medium through which the wave travels is the same direction as the wave is moving, then the wave is **longitudinal**. On the other hand, if the vibrational disturbance in the medium is perpendicular to the direction of wave motion, then it is a **transverse** wave. Other forms of waves that combine these two simple relations also exist, but it is unnecessary to study them at this time. Sound is a longitudinal wave, while light is transverse. Ocean and water waves are very nearly transverse with a small amount of longitudinal motion thrown in. Some physical phenomena such as earthquakes produce both kinds of waves. A demonstration of wave motion can be found at www.kettering.edu/~drussell/Demos/waves/wavemotion.html and hyperphysics.phy-astr.gsu.edu/hbase/sound/wavplt.html .

Sound is probably the single waveform with which we are the most familiar. We are so familiar with sound that we have developed a special language to describe sounds. For instance, one may speak of an **ultrasonic** sound. Humans only hear sounds within a specific range of frequencies, 20 to 20,000 Hertz. Any frequency above the human range is called ultrasonic, while any sound with a frequency below the human range is **infrasonic**. These terms, like others, are defined relative to humans. Other animals can detect sounds outside of the human hearing range. Dogs can hear sounds of higher frequencies, therefore, they hear dog whistles which humans cannot hear. These ranges are not absolute, and even some humans can hear frequencies outside of these extremes. But when we talk about hearing sounds, we do not usually use the word frequency which isd a physics term. We generally use the term **pitch**, which is the physiological equivalent to frequency in physics.

Waves, in general display other characteristics. A wave will bounce at surfaces between two different media, a property called reflection. When waves undergo reflection, they actually reverse direction, so, when you see your reflection in a mirror, your right and left sides have been exchanged. Reflecting sound waves also cause a common phenomenon called an **echo**. Waves will also bend as they travel from one medium into another, a property called refraction. If you stand in a shallow and clear pool of water, you can stick a straight piece of wood into the water and it will appear to bend at the surface of the water. The bend is an illusion caused by the fact that the light waves coming to your eyes from below the water bend away from the stick as they come from the denser water into the less dense air. And finally, waves with bend around an obstacle in their path, bending into a shadow area behind the obstacle. This last property is called diffraction. Therefore, you can hear a person yelling at you even when they are standing behind a building. The sound waves bend around the building so the person can be heard within the shadow area of the sound.

Diffraction is also important because it supplies the special conditions for another property of waves. Waves can add together in a special manner called superposition. If the positive amplitude of one wave arrives at the same spot and time as the positive amplitude of another wave, they add constructively to give a larger amplitude. This results in a much louder than normal sound. This phenomenon occurs when the distance traveled by the two waves are whole number multiples of their wave lengths, which guarantees that a positive amplitude will meet a positive amplitude. However, if the positive amplitude of one wave corresponds to the negative amplitude of another wave, then the interference between the two waves is negative and they cancel each other out completely. This phenomenon is called destructive interference and it causes a dead or hollow spot in the sound, nothing is heard at that point. In general, when the distances traveled by two waves are different by a half multiple of the wavelengths, it is guaranteed that a positive and negative amplitude correspond to each other and cancel each other.

The diffraction of a wave around an obstacle creates two equal portions of a wave that interfere with each other when they bend into the shadow zone behind the obstacle. The interference that is established in this manner shows up as a pattern of loud sounds and dead spots for sound waves, and as a series of bright spots and dark spots for light waves. Only waves display this type of interference. When two similar waves come from different sources, but have very nearly the same frequency, they interfere in a unique manner by producing **beats**. The number of beats per second is just equal to the difference in frequencies between the two sounds. The quality of a very complex sound depends on these beats and they form an important component of music.

These issues bring up another issue called the intensity of sound. The **intensity** of a sound tells how the energy and power of a sound spread out over space as the sound travels away from its source, so the intensity equals the power of the sound divided by the cross sectional area of the expanding spherical wave front. While intensity is a physical quantity, it is related to the loudness of a sound that is relative to the human ear and is a strictly physiological term. The loudness of a sound in measured in units called decibels. Since the loudness scale, also called the **decibel scale**, is a logarithmic scale where an increase of ten decibels actually means the sound is ten times louder. In other words, every increase of ten decibels means that the sound is a power of ten louder. An increase in loudness of 60 decibels (6 times 10) would actually mean the sound is 10 to the sixth power, or 1,000,000 times louder.

Sounds also display a special quality called resonance. If a sound of a particular wavelength comes into contact with a material object whose length in the direction of the sound is equal to the sound's wavelength, the object will begin to vibrate at the same frequency as the incoming sound. This property is called **resonance**, and every material object has its own unique resonant frequency. If that object is struck, it will vibrate at a special unique frequency called its resonant or **natural frequency**. This frequency is important, especially in the case of musical instruments. For example, a string fastened tightly at each end can be plucked or struck and it will resonate at its own natural frequency, emitting a sound at exactly that frequency. That frequency is called the fundamental frequency or tone of the string. If the length of the string is halved, say by pinching the string at its midpoint between two of your fingertips, the natural frequency will double, and this is called the first overtone of the string. This particular relationship defines all of the stringed and percussion instruments that humans have invented. Similar relationships exist for the wind and reed instruments, allowing the physics of sound to explain and account for all of the science of music.

And finally we have one last common phenomenon associated with waves and sound that needs explanation; the **Doppler effect** and its cousin the sonic boom. If you stand at the side of a road as a car passes blowing its horn, the pitch of the horn is higher as the car approaches you, falls to its actual pitch as the car becomes even with you, and then decreases as the car rushes away from you. This change in pitch or frequency is called a Doppler shift. It occurs because the speed of the sound coming toward you adds to the speed of the car coming toward you, in effect, compressing the sound wave into a shorter distance and giving it a higher pitch. As the car pulls away from you, the speeds subtract, extending the waves and yielding a lower pitch. This phenomenon is related to a **sonic boom**. As a jet approaches the speed of sound, the sound waves that it is emitting become compressed. Just as the jet passes through the barrier of sound, accelerating through and past the speed of sound, all of the successive compression (condensation) portions of the emitted sound wave front coincide and become a single extremely intense shock wave. This shock wave or rapid pulse is extremely loud, and is detected on the ground as a sonic boom. A sound wave tutorial with links to the different properties and sound phenomena can be found at csgrad.cs.vt.edu/~chin/chin_sound.html .

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Writing assignment: Complete the 'Activities' on pages 124 and 134. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 3.

Complete all of the 'Questions for Thought' on page 143 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 3.

Complete the Group A and Group B exercises on pages 143 and 144. Send the answers to the Group B exercises to the instructor via email. Your answers are due by the end of week 3.

Lecture 7:
Electricity

Electricity is another very old phenomenon that withstood reduction to scientific analysis for many centuries. It was only the success of the Newtonian worldview and Newtonian mechanics that allowed a complete explanation of electricity and magnetism by the end of the eighteenth century. However, the road to understanding electricity and magnetism came slowly, following on the tail of the Newtonian revolution. Newton knew of both phenomena, and perhaps he guessed that they were intimately related, but bringing electricity and magnetism together using one theoretical framework took many centuries. The ancient Greeks and probably earlier thinkers knew of electricity, but the first records of its study come from the Greeks. They knew that a piece of amber would develop an electrostatic charge when rubbed by a piece of rabbit fur. In fact, the Greek word for amber is "elektrik," which is the origin of the English word electricity.

We now know that electrical charge is a basic property of elementary particles. That is, particles that are smaller than atoms and, in fact, makes up the atom. The nucleus of an atom is composed of protons, with positive charge, and neutrons, with no charge. Electrons that have negative charge of an amount equal to the proton's charge orbit the nucleus. All charges are equal, it is just that some are positive and some are negative. The **fundamental charge** is 1.6 x 10^{-19} Coulombs. The negative electrons are attracted to the positive protons in the nucleus, holding the atom together. The rule is that like charges repel each other and unlike charges attract each other. The protons in the nucleus do not repel each other as is normal, because they are bound together by an even stronger force called the strong nuclear force, which will be studied later.

The outermost electrons in an atom are less attracted to the nucleus, especially in larger atoms. So, when the rabbit fur rubs against the amber, negative electrons are knocked off of the fur onto the amber, giving the amber an overall negative charge. This charge is called an **electrostatic charge** because the electrons are not moving as is the case in current electricity. The other standard for electrostatics is a glass rod rubbed by silk which gives the glass rod a positive charge. Since only electrons are changing position, since protons are bound in the nucleus and cannot move freely, the silk rubs electrons off of the glass rod to give it an overall positive charge. You can find more information on static electricity at www.school-for-champions.com/science/static.htm .

Charge can move from body to body by the transfer of electrons or by induction, the forced polarization of charge on a neutral body by a close proximity to a charged body. When bodies attract or repel they do so with a force that is equal to the product of the charges on the bodies divided by the square of the distance between the charged bodies and multiplied by an electrostatic constant which is equal to 9 x 10^9 Newton-meter^2/Coulomb^2. This force is called the Coulomb force, named after the scientist who derived the relationship in the late eighteenth century. In reality the charges do not interact with each other. They establish electrical fields around them and the interactions come between the electrical fields rather than the particles themselves. When a particle is placed within the electric field of another particle, it feels a force of attraction or repulsion, whichever the case may be.

The electric field can be pictured as being inhabited by lines of force or field lines, which are imaginary lines representing possible paths that particles with charge would travel upon, similar to the trajectories of a thrown object in a gravitational field. The lines of force travel radially outward from positive charges and radially inward toward negative charges. The electrical field also represents an electrical potential around the charges. Potential changes as you go further from the charged particle, either increasing or decreasing depending upon whether the source particle is positive or negative. Between any two points in the filed there is a potential difference, which is measured in **volts**. When a charged particle is placed in a field, it gains a potential energy relative to the field source, similar to the gravitational potential energy. That means that the potential difference in volts is analogous to the acceleration due to gravity g. It takes work to move a charge in a potential field through a potential difference, so work in Joules equals the potential difference in volts times the electrical charge q in Coulombs.

In general, there are two types of material bodies; Conductors that allow electrons to pass through them and insulators that will stop electrons from passing through them. Metals make good conductors because they have a good number of free electrons within their bodies. When a potential difference is placed at two ends of a conductor, free electrons in the conductor move according to the direction of the field in the conductor, thus generating and **electric current**. The electric current is defined by the number of charges that pass by in a given amount of time and is measured in units of **amps**. A battery usually supplies the potential difference in a circuit, a loop of conductor wire, so the current travels in a single direction all the time. This is called **direct current (dc)**. By international convention, current travels from the positive to negative battery terminals. But electricity from a wall socket is **alternating current (ac)**, which goes first one direction and then another, switching direction 120 times a minute for 60 cycle current as used in the United States.

The wire through which the current travels actually resists the flow of current by internal friction. The electrons moving through the metal conductor bump along from atom to atom, and thus their motion is resisted. The amount by which a conductor resists the flow of current is called the **electrical resistance**, and it differs from conductor to conductor with insulators effectively having infinite resistance. The relationship between the potential difference or voltage (V) and the amount of current (I) passing through the conductor is a measure of the resistance (R), in other words

$$R = V/I,$$

which is commonly known as **Ohm's law** and the unit of resistance is called an Ohm. Even NASA talks about Ohm's law at www.grc.nasa.gov/Other_Groups/K-12/Sample_Projects/Ohms_Law/ ohmslaw.html .

The electron has mass so it takes work to move an electron through the wire. That work is supplied by the battery or other electrical source (that's why batteries eventually wear out and die), and thus we have a power drain across the conducting wire such that P = Work/time. The power dissipated by the wire is thus equal to the product of the current and voltage or P = IV, which means that a **Watt** = Amp-Volt. The power dissipated by the resistance in a wire must have some physical signature, and it is easy to see how this power loss appears. The resistance in the conducting wire is similar to an internal friction that electrons experience on passing through the wire, and just like normal friction when you rub your hands together, the resistance of a wire causes a build up of heat in the wire. That heat is dissipated according to the laws of thermodynamics, but the heat loss means an energy loss by the battery that moves the electrons. It is the heat loss due to resistance that causes the power loss across a conducting wire.

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Writing assignment: Complete the 'Activities' on page 149. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 4.

Complete the 'Questions for Thought' from number one to six on page 181 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 4.

Complete the Group A and Group B exercises on page 181. Send the answers to the Group B exercises from one to ten to the instructor via email. Your answers are due by the end of week 4.

Lecture 8:
Electricity and Magnetism

We have known about magnetism for millennia, dating back to the Greeks and Chinese civilizations, but it was only during the scientific revolution that magnetism became a subject for scientific concern. The first practical use of magnetism came with the compass, which Marco Polo reportedly brought back to Europe from China. More on this subject can be found at www-istp.gsfc.nasa.gov/Education/Imagnet.html. The compass was of tremendous importance during the era of western exploration of the world by sea and William Gilbert published the first book on the subject, *De Magnete*, in 1600. Gilbert was the first to explain that a compass needle pointed to the north and south because the earth had a magnetic field.

After this, not much scientific work was done on magnetism because science did not have the proper tools to explore the subject, so magnetism remained little more than a scientific curiosity for the next century. The real progress toward a science of magnetism came only after 1800 when it was discovered that electricity caused magnetism. There had been suspicions of a relationship between electricity and magnetism for some time since it was well known that lightning had the ability to magnetize metal objects. However, it was only with the discovery of electrical current and the subsequent development of the battery in 1800 that created sufficient electrical current through a conducting wire to find how electricity caused magnetism.

In 1820, Hans Christian Oersted discovered that a current carrying wire could produce a **magnetic field** around it. He found the effect by accident while performing a lecture. Others had looked for the effect, but had failed to find it because they looked for compass needles to point directly at the wire believing that the magnetic force was point to point directed like gravity and electricity. But Oersted found that compass needles lined up circularly around the wire instead.

Michael Faraday who reasoned that a magnetic field could be used to generate an electric current in a wire took the next important steps. Faraday was able to demonstrate this phenomenon a decade later, and his designs have become the basis of all electrical generators and motors. Faraday was an exceptional scientist who made many discoveries and laid the foundations for Maxwell to complete the electromagnetic theory. Faraday who had to picture the physical effects in his mind and find a way to express his ideas for others since he had no background in mathematics and no formal education developed the whole concept of a field. Yet he was one of the greatest scientists who ever lived, a reputation that was built upon his purely experimental work and his profound understanding of the world around him.

Later research eventually resulted in the discovery that moving electrical charges are the source of all magnetic fields. A stationary electric charge, no matter what the source of the charge, generates an electric field radially outward. But once the charge starts moving, it begins to generate a magnetic field in circles around it. Both fields are stronger closer to the field source, and weaken as the inverse ratio of the distance from the field source squared ($1/r^2$). But the magnetic field actually gains strength as the charged particle moves faster and faster, it is speed dependent. In the case of the current carrying wire, the magnetic field around the wire is the combined result of all the electrons that are moving through the wire and thus contributing to the current.

Permanent magnets also result from the motions of charged particles, in particular, the electrons orbiting the atomic nucleus. In other words, every atom is a tiny magnet due to its orbiting electrons. However, these little magnets have many different orientations, strengths and characteristics because of the complicated interactions between different electrons in the larger atoms. Ferromagnetic substances, such as iron and nickel, form the strongest permanent magnets because their atomic structure allows the greatest possible alignment of the individual atomic magnetic moments. The single strongest is iron.

Nature actually makes its own magnets. They are rock deposits from iron rich molten volcanic material that cools down below the Curie point, a temperature above which the natural alignment of internal magnetic fields in a substance is disrupted. As the iron bearing magma cools down, the atomic magnetic moments align with the earth's magnetic field to leave a permanent magnet, which could be lodestone, magnetite of other rock type. The individual magnetic moments of the iron magnets line up into larger groupings called **magnetic domains**. In non-magnetized iron, the domains point in all directions and cancel each other's magnetic fields, but when the domains align with one another they add together to produce the net magnetic field of a piece of magnetized iron

When another piece of iron, such a non-magnetized bit of iron, comes near a magnet, the field from the magnetized iron induces a temporary magnetic field in the non-magnetized bit of iron. But the temporary induced field is in the opposite direction to the field that induced it, so the iron bit is attracted to the permanent magnet, South Pole to North Pole and North Pole to South Pole. Magnets are not point charges like electric charges, and have poles. In other words, you can never have a magnet with a north pole without a south pole and vice versa. Magnets are always dipolar, while electrical charges are monopolar (they can exist independent of each other). So, if you cut a magnet in half, you just get a smaller magnet with two opposite poles, and the process continues as long as you continue to cut the magnet into smaller and smaller pieces down to the atomic level. The magnetic field of the permanent magnet loops around in circles from the north pole to the south pole outside of the magnet and then continues through the magnet itself, the lines of force are continuous and do not end at the magnetic poles the same way that electrical lines of force end when they touch their point charge sources.

The earth is a giant magnet. The magnetic field is probably due to charged particles or ions moving within the core of the earth. To the best of our knowledge, the core of the earth is solid iron with a small percentage of nickel. This inner core is surrounded by a liquid iron outer core of the same material, then molten rock in the form of magma, and finally a thin rock crust which forms the ocean floors and continents on which we live. Other planets, moons, stars and assorted heavenly bodies also have magnetic fields, which our scientists study to learn more about the earth and its origins. The earth rotates on its axis and the points where the axis passes through the earth form the true north and true south poles. The magnetic north and south poles do not exactly coincide with the true poles, so magnetic needles do not point to true north and true south. In order to find true north and true south from compass directions, you therefore need to compensate for the difference between the magnetic poles and the true poles.

We can simulate the magnetic field's structure of a planet like the earth by forming a circular wire loop and putting an electrical current through the loop. A magnetic field generated around the wire in such a loop will enter one side of the loop through the center and then curl around the wire to reenter the loop at the same points. The magnetic field lines would look something like the sections of an orange with the wire loop stretched around the equator of the orange, perpendicular to the sections. The magnetic field within the plane of the loop is uniform when the loop is a perfect circle of wire. Uniformity means that the direction of the field and the strength of the field is the same at all points. If a large number of loops are placed alongside each other like a stack of papers, with no separation between them, to form a cylinder like structure of one continuous wire, the magnetic field inside this "solenoid" or "coil" will be uniform throughout the whole inside volume of the structure. The coil would form an **electromagnet** when an electrical current is applied. The magnetic field lines would look exactly like those of a permanent magnet, except that the center of the coil is hollow so you could imagine the field lines continuing through the coil without interruption and emerging from the other end of the coil.

If another coil (the secondary) is placed next to the first one (the primary), or even inside the first one, and a current is applied to the first coil making an electromagnet, a temporary magnetic field is induced in the secondary coil. The induced magnetic field in the secondary coil is directed in the opposite direction to the primary coil, so that they attract each other. This process is known as **electromagnetic induction**. A direct current would produce only a momentary induced field in the secondary coil, since the secondary magnetic field is induced only by a change in the field strength of the primary coil. However, if an alternating current is applied through the primary coil, which is a constantly changing electrical, current, the primary magnetic field is constantly changing so the induced magnetic field in the secondary coil is permanent, but constantly changing direction and strength at the same rate as the alternating current in the primary coil. Even if you place an unmagnetized iron bar inside the primary coil when a current passes through it, the electromagnet induces a magnetic field in the iron bar, while the iron bar then bolsters and increases the strength of the field within the center of the coil.

The double coil system or variations of it, either with or without an iron core, forms the basic mechanism for all types of electrical devices from doorbells, fire alarms, and stereo speakers, to galvanometers, ammeters and voltmeters for measuring electrical quantities. One of these devices, the **transformer**, is of special importance. If the primary and secondary coils have the same number of loops, the induced current and voltage in the secondary are the same. However, if the primary and secondary coils have a different number of loops or turns, the induced current and voltage in the secondary coil differ from those in the primary by the ratio of the number of loops in each coil. Such devices are called transformers and are used to convert voltages for different uses. Suppose you have a transformer with a primary coil of 120 loops and a secondary coil of 60 loops. If the potential difference across the primary is 20 volts, then the potential difference across the secondary coil would be 10 volts and the device would be called a step-down transformer.

If the positions of the primary and secondary coils were reversed, it would be a step-up transformer and it would increase the voltage by the reciprocal ratio. You are not really losing anything by the decrease in voltage in the step-down transformer because the current would then increase by the same ratio. If the value of the current in the primary is 5 amps, then the current in the secondary would be 10 amps. The decrease in voltage accompanied by a proportional increase in current, or vice versa, guarantees that the power input is the same as the power output, satisfying the conservation of energy. These values would only be true for an ideal transformer. In actuality, power is lost during the process due to the resistance in the wires, so these values would not be completely accurate. However, when power loss is taken into account, you could calculate the resulting potential difference and current with no trouble. Such transformers are used throughout the world in numerous different applications.

Even an electric motor has a similar structure. If you place two magnets or electromagnets end to end with an air gap between them and opposite poles facing each other, you establish a roughly uniform magnetic field between the poles. If you then place a coil bundle of wire in the air gap and put a direct current through that coil bundle, it will begin to turn on its own initiative and then gain speed up to a maximum speed. This device constitutes an electric motor. The current through the coil bundle creates a magnetic field around the coil bundle, which in turn is alternately attracted and repelled by the external magnetic field, causing the coil bundle to turn at high speed. Quite simply, your put current into the coil and get motion out.

On the other hand, using exactly the same device, do not put any current through the coil bundle. Instead, connect it to either a voltmeter or ammeter to measure the electrical output of the device. Then turn the coil by hand. You will notice that an electrical current is induced in the coil bundle and thus showing a current in the electrical meters. Turn it faster, and you produce still more current, or a higher voltage. If you put motion into this device, you get electricity out, just the opposite of the case with the electrical motor above. When the coil bundle is turned by hand, the wire moves, so the free electrons inside the metal wire move relative to the external magnetic field. By moving, the free electrons generate their own little magnetic fields around them, which interact with the external magnetic field to attract or repel them. But the moving free electrons cannot move either toward or away from the external magnetic poles because they are restricted to only move within the wire, so they move through the wire. Thus, a current is established in the wire. Since the turning coil flips over during its circular motion, the current that is produced first goes in one direction and then the other, changing direction at the same rate or frequency as the turning coil bundle. Such an electric generator thus produces alternating current. Very large generators of this same basic design are called dynamos. They are turned by either falling water, as in hydroelectric power plants, or by steam produced by the heat from controlled nuclear reactions, as in nuclear power plants. Transformers, using basically the same design as described above, are then used to decrease the current produced to usable voltages in your home, school or workplace.

The final theory that evolved from this process is called electromagnetic theory. It was completed by James Clerk Maxwell, a student of Faraday's, by the 1860s. The changes wrought by this new theory and the work that preceded it were instrumental in fueling and running the machinery of the Second Industrial Revolution during the nineteenth century. If you look around today, you will be unable to find any facet of culture or civilization that has not been affected in some manner by the electrical devices that were invented during this period. Yet this does not complete the story of electromagnetism.

For general information on the physics of magnetism you can go to www.wondermagnet.com/dev/magfaq.html .

Comprehensive web pages on electricity and magnetism can be found at the following addresses:

theory.uwinnipeg.ca/mod_tech/node83.html .

buphy.bu.edu/~duffy/electricity.html .

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Writing assignment: Complete the 'Activities' on page 149. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 4.

Complete the ‘Questions for Thought’ from number one to six on page 181 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 4.

Complete the Group A and Group B exercises on page 181. Send the answers to the Group B exercises from one to ten to the instructor via email. Your answers are due by the end of week 4.

Lecture 9:
Light

The nature of light has been one of the greatest mysteries throughout the history of human thought, and is not completely understood, even today. Many theories have been proposed to explain light, including one during the middle ages that proposed that we emit light from our eyes to the objects that we see and the light thus acts like a blind man's walking stick as we feel our way through physical reality. The first modern sounding theories were products of the Scientific Revolution of the seventeenth century. European scientists thought that blight was a wave, but they could not prove their hypothesis. On the other hand, Newton thought that light was corpuscular, or light was particles. Newton actually bested to see if light could be waves, but to no avail.

Light has the property of **reflection** and **refraction**, but particles can bounce off of barriers (reflection) and their paths bend when they pass from one medium to another (refraction), so these properties cannot be used to experimentally distinguish between light waves and light particles. However, light waves can diffract, or bend around obstacles, and particles cannot. **Diffraction** can then be tested in experiments designed to look for **interference** patterns that should appear after diffraction occurs. Only this test can distinguish between the wave or particle nature of light. Newton performed experiments to find these interference patterns of light, but his brightest light source was direct sunlight coming through a pinhole in the wall into a darkened room, and that light source was not bright enough to detect the interference patterns he sought. So, Newton accepted the particle theory of light and Newton's influence became so strong that the rest of the scientific world came to accept his view. It was not until the nineteenth century that the theoretical basis of light changed, and then only after other crucial changes had come to science.

The rules for applying the laws of reflection and refraction were well known by the early seventeenth century, allowing for the development of the microscope, telescope and other optical instruments. Scientists used a geometrical model called the **light ray**

model to understand light at this early stage of development. The law of reflection, which states that the incoming angle of a ray of light equals the reflected angle of a ray of light from a reflective surface, allows the geometrical analysis of mirror images and other reflections. A **real image** will appear for a mirror curved inward, such that the light will focus to an image that can be seen on a screen. However, a flat mirror or a mirror curved outward at its edges will produce a **virtual image**. You can see an image in the mirror in the virtual case, but the image will appear to focus behind the mirror. Mirror images also reverse the image, right for left.

On the other hand, the law of refraction states that light entering and traveling through denser media will bend in one direction and light entering less dense media will bend in the opposite direction. The degree that the light rays bend depends upon ratio of special numbers representing the density of the media called **indices of refraction**. The index of refraction for empty space is 1.0, by definition, for air it is so close to 1.0 that 1.0 can be used in all cases and for glass it can be between 1.4 and 1.6 depending on the type of glass. All substances have a characteristic index of refraction by which they can be identified and this identification is used to determine the identity of precious gems. The law of refraction and indices of refraction can thus be used to explain how light travels through lenses to be either focused to a point for a real image, or dispersed for a virtual image. The understanding of this law preceded the invention of eyeglasses, telescopes and microscopes. A very complete summary of geometrical optics can be found at members.tripod.com/~IgorIvanov/physics/optics-geom.html and web.mit.edu/redingtn/www/netadv/optics-geom.html. Just follow the links for a complete description of optical phenomena. Explanations of other phenomena soon followed. Newton explained the rainbow of colors coming from a prism, discovering that white light is a combination of all the colors of the rainbow.

The year 1800 saw the development of the battery, which was soon followed by the invention of carbon arc lamps and other bright light sources that could be used for scientific experimentation. In 1801, Thomas Young was able to detect those unseen diffraction or interference patterns that Newton had missed using the newer technologies, but even then, Newton's influence was so strong that Young was not at first believed. Within a few years, his experiment was repeated by other scientists and the wave theory fo light was instituted within the scientific community. Be this as it may, the problems regarding the nature of light were still far from resolved with this discovery. No one knew what kind of waves light made, nor did they have any idea what kind of medium the waves traveled through. These advances came at the same time that the theories of electricity and magnetism were being developed and unified by Faraday and others.

In the 1850s and 1860s, James Clerk Maxwell adopted and adapted Faraday's conceptual models of the electric and magnetic fields, combined these with the work of other scientists, and added his own small changes within a single mathematical model to develop the theory of electromagnetism, essentially the same as it is accepted today. His theory was based upon four laws; (1) electrostatic charges are monopolar; (2) magnets are dipolar; (3) a changing electric field generates a magnetic field; and (4) a changing magnetic field generates an electric field.

From these four laws, Maxwell was able to describe light as an electromagnetic wave composed of changing electric and magnetic fields directed at right angles to each other, traveling at a right angle to the plane of the varying fields. From this model, Maxwell was further able to derive a formula for the speed of light that matched the already measured speed of light, 3×10^8 meters/second. His accurate prediction of the speed of light from theory convinced many scientists to accept his theory, but there were a few holdouts. Then, in the 1870s, Heinrich Hertz was able to send and detect electromagnetic waves outside of the visible light spectrum, as predicted by Maxwell's theory. So the rest of the scientific community came to accept the theory as a true representation of the nature of light. The spectrum is given at www.misd.org/sci-tech/2001/mhs/123/. Today, we know that the medium through which electromagnetic waves travel is the same varying electric and magnetic fields from which light is composed, so light can travel through the vacuum of outer space without requiring a material medium.

We have also expanded the electromagnetic spectrum by discovering many other types of waves outside of the visible portion of the spectrum. The visible light spectrum ranges from red light with a wavelength of 700 nanometers (10^{-9} meters) to violet light at 400 nanometers. Shorter wavelengths mean higher frequencies and thus higher energies. Longer wavelengths mean lower frequencies and thus lower energies. Red light thus represents the low energy end of the visible spectrum. Then we have electromagnetic waves of less energy, beginning with infrared waves, microwaves, short waves, medium waves and long waves. By the time we get to the longest waves, the wavelengths are millions and thousands of meters and the energy is so low that it is difficult and perhaps impossible to detect. At the other end of the spectrum, with ever increasing energy and shorter wavelengths, we pass through violet light to ultraviolet waves, x-rays, gamma rays, and cosmic rays. By the time we get to the high energy gamma rays and cosmic rays, the energies are extremely high, but the waves shorter than the width of a single proton, so the waves become undetectable.

Maxwell's theory was perfectly compatible with all of the previous explanations of light related phenomena, however it failed to unify perfectly with those phenomena that combined Newtonian mechanics and light. For example, if you throw a ball forward at 10 meters/second when you are running at a speed of 15 meters/second, the speed of the ball relative to a person standing still would be 25 meters/second. Speeds add together in a process called Galilean relativity. But according to Maxwell's electromagnetic theory, the speed of light is constant, so if a car moving at 60 miles/hour turns on its lights to emit a beam of light at the speed of light c, a stationary observer will still see the light traveling at the speed c. Light rays or waves do not add according to Galilean relativity and thus Newtonian mechanics. Albert Einstein solved this problem in 1905, but in the nineteenth century it remained an unsolved problem for science, and it was only one of several problems brought on by the successful application of Maxwell's theory.

Blackbody radiation and the **photoelectric effect** also posed seemingly insurmountable problems for scientists. A blackbody is a perfect absorber and emitter of light waves according to Maxwell's theory. When a blackbody, such as a lump of charcoal, is heated, it first glows red-hot, then orange and possibly yellow before it glows white-hot. When the glow of the heated blackbody goes through this sequence of changing colors, it is actually going through the spectrum of visible light according to the increasing energy of the different colors of light. By the time it gets to white light, the heated blackbody is emitting all of the colors of the spectrum equally which yields the white light. But an analysis of the light shows that the equal emission of all colors as required by Maxwell's law is not true. So something is not happening according to the known laws of nature and the accepted theories to explain light and mechanics. Ernst Planck came up with a theory that solved the problem by assuming that not all frequencies of light were emitted. Instead, only specific frequencies of light were emitted in small packets called **quanta**. These quanta of light had specific energies related to the their energy according to the formula $E = hf$, where h is a constant now called Plank's constant. It is equal to 6.63×10^{-34} Joule-seconds. For more on this subject go to theory.uwinnipeg.ca/physics/quant/node2.html.

Plank's quantum theory of 1901 saved the day, but introduced the possibility that light waves could actually be particles. Einstein used Plank's quantum to explain the photoelectric effect in 1905 and thereby demonstrated that light occurs as particles, called **photons**. But this successful explanation of the photoelectric effect introduced another problem that has baffled scientists to this day. For a simple explanation of the photoelectric effect, go to www.colorado.edu/physics/2000/quantumzone/photoelectric.html and zebu.uoregon.edu/~js/glossary/photoelectric_effect.html. We now accept the fact that light can sometimes act as waves, for instance during diffraction/interference experiments, but light can also act as particles called photons in other phenomena, such as photocells and lasers. So what then is light? A wave? A particle? Neither? Or both? This dilemma is called the wave/particle duality and it brings us to the modern view of light. Light can be either a wave or particle, depending upon the experiment that we use to test the light. These problems and their solutions as bring us to a new phase in physics, the transition between what is called classical physics, or physics before 1900, and the modern physics we now study. Modern physics includes quantum theory, which explains the atom and nucleus, and relativity theory that explains the universe as a whole.

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Writing assignment: There are no 'Activities' in Chapter 8.

Complete the ‘Questions for Thought’ on page 206 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 5.

Name: __________________________ Integrated Science 101 – Final Exam

Complete the Group A and Group B exercises on page 207. Send the answers to the Group B exercises from one to ten to the instructor via email. Your answers are due by the end of week 5.

Lecture 10:
Atomic Structure

The nineteenth century ended with many new advances and discoveries in physics. J.J. Thomson discovered the electron in 1897 and Henri Becquerel found the first example of radioactivity in an element in 1896. Radioactive decay produced alpha and beta rays that were at first thought to be electromagnetic waves, but later found to be material particles traveling at very high speeds, as well as gamma rays which were later shown to be very high energy electromagnetic waves. Alpha rays are actually helium nuclei traveling and beta rays are ejected electrons. Although it was known that the electron carried a negative electrical charge, it was not until a decade later that the electronic charge was finally measured by Robert Millikan. In retrospect, these discoveries were quite unexpected given the fact that many scientists only considered atoms themselves hypothetical objects at the time. The truth of the existence of an atom came only at the end of the first decade of the twentieth century.

The first atomic theory dated back to the Greek philosopher Democritus, but the atomic concept of a smallest particle of matter had fallen in and out of vogue over the centuries. In Newton's day, some scientists more-or-less considered the possibility of atoms, but no real atomic theories were proposed. The first modern atomic theory came in chemistry in 1812 and was proposed by John Dalton. Ever since that day, atoms had been used in many ways, but their existence was never a foregone conclusion. Then, in the 1890s, the first subatomic particles were discovered. At that time, physicists thought that should atoms exist, then they must vibrate in some manner to absorb and emit the electromagnetic waves that had been detected, but there were no other clues to suggest the structure of the hypothetical atoms. Thomson, the discoverer of the electron, proposed a plum pudding model of the atom based upon the suspected modes of vibration of the atom. His model was like a pudding or jello with raisins in it. The pudding was positively charged and could vibrate like a lump of jello on a plate, while the raisins were actually negative electrons scattered throughout the pudding. The electrons were also thought to vibrate about their positions. The combined charge of the positive pudding and negative electrons added to zero, so the atoms were electrically neutral as observed.

This model only lasted a decade before it proven false by experiment. In 1912, Ernst Rutherford bombarded a thin gold sheet with alpha particles. The alpha particles were like small high-speed bullets so they were expected to rip through the Thomson pudding atom without being deflected, like bullets through a jello cup. But, to Rutherford's surprise, a few of the alpha particles scattered at large angles and an even smaller number actually rebounded backwards. Although most went through the gold foil sample, Rutherford knew that the pudding model of the atom could not explain such radical scattering. So, he developed the planetary model of the atom that is approximately the structure that we accept today. Since most of the alpha particles went through the atom unscathed, Rutherford concluded that the atom is mostly empty space. But since a few scattered backwards, the atom must have a very dense and extremely small **nucleus**. This model would look something like our solar system, with most of the mass concentrated in the sun while the relatively small planets orbit the sun at a very great relative distances, whence the name planetary model.

Within a few years, the nucleus of the atom was found to be composed of positive **protons** and neutral **neutrons**. The proton was discovered by Rutherford in 1917 and James Chadwick discovered the neutron in 1932. The masses of these two elementary particles are very nearly the same, yet they are about 1800 times more massive than the electrons that orbit the nucleus. So almost all of the mass of an atom is concentrated in the nucleus that is very small compared to the overall size of the atom as determined by the orbital diameters of the electrons. The electrons and protons have equal but opposite charges, so that the attraction of the electrons to the positive nucleus keeps them in orbit.

The atoms themselves represent the different elements found in nature. An atom is the smallest material unit that can be derived by chemical or physical means and still be identified as a chemical element. Every element can be identified by an **atomic number**, which is equal to the number of protons in the nucleus. The number of protons in the nucleus determines which element is present. Every atom also has an atomic mass which is equal to the total number of neutrons plus protons that are present in the nucleus. Many elements can come in different forms because they have the same number of protons, so they are the same elements, but they have different numbers of neutrons, so they have different masses. They are called different isotopes of the same element. When a nucleus has too many neutrons in ratio to the protons in its nucleus, the nucleus is unstable and will decay into another element. This and other properties of the nucleus will be discussed in the next lecture. However, the nucleus cannot account for the different frequencies of light that can be absorbed and emitted by the atoms as a whole. The emission and absorption of electromagnetic waves by the atom occurs in the electron orbits around the nucleus.

A young student named Nils Bohr came to study with Rutherford in1913. He was determined to explain the characteristic spectral lines of the hydrogen atom. The specific emission and absorption spectra of hydrogen and other substances had been known and studied for several decades, but their origin was still a mystery. These spectra were like fingerprints that were used to identify different substances. Bohr took Plank's quantum theory and hypothesized that electrons orbited the nucleus as quanta. The electrons could only exist in specific fixed orbits that were characterized by the principle quantum numbers of 1,2,3,4, and so on. Each of these orbits represented a specific allowable energy state of the orbiting electron. No other energy states were allowed.

When light of a particular wavelength or frequency whose energy perfectly matched the difference between two of these energy states came near an orbiting electron, the electron would absorb the whole energy of the light wave, as if the wave were a particle, and the electron would jump to the higher orbit. Only those specific photons, or light particles, whose energy perfectly matched the difference in energies between allowable states or orbits, could be so absorbed. From his theoretical model, Bohr calculated that those photons that matched these energy transitions were the same light waves that were observed in the absorption spectra of hydrogen.

When an electron is in a higher energy state or orbit, the orbit is unstable and the electron automatically falls into a lower energy state closer to the nucleus. The lowest possible orbit or energy state that an electron could occupy is called the ground state of the electron. When an electron falls into its ground state, it would lose exactly the amount of energy equal to the difference between the **excited state** that it had occupied and its **ground state**. That exact energy was emitted as a photon of the same energy and no other energy. When Bohr, calculated the different possibilities for all such energy transitions according to his electronic model, Bohr found that his model predicted all of the possible emission lines in the hydrogen spectrum. So, by quantizing the electron orbits around the nucleus according to Planck's quantum theory, Bohr was able to predict all of the known absorption and emission spectra lines for hydrogen. His model of the atom is now known as the Bohr model and is still used today. Today, science has applied the Bohr model to all of the elemental atoms and this has allowed science to explain many different phenomena including the placement of elements in the periodic table of elements and the particular configurations and structure of molecules which form from atoms to make different chemical substances.

In 1923, Louis DeBroglie took the Bohr model of the atom one step further and explained why only those particular energy states predicted by Bohr were allowed in an atom and no others. Einstein had found in 1905 that electromagnetic waves could act as if they were particles called photons under some conditions. Bohr then hypothesized that light waves were absorbed and emitted as if they were particles to explain the orbits of electrons in an atom. DeBroglie turned these arguments around and hypothesized that moving material particles should be able to act like light waves according to the relationship that the matter wavelength = h/mv. So, moving electrons and other particles could be diffracted and show interference as could all other waveforms. This would mean that the lowest electron orbit in the hydrogen atom, its ground state with a principle quantum number n = 1, corresponds to the situation where the orbital path followed by the electron would exactly equal one wavelength of the moving electron. The orbital path for the second energy state, where n = 2, would exactly equal two wavelengths of the moving electron and so on.

Therefore, the allowable energy states corresponded to those orbital radii or positions where an electron would constructively interfere with itself and reinforce its existence as it orbited the nucleus. All of the other orbital positions, which were not allowed in the Bohr model, corresponded to electron waves that interfered destructively with themselves and thus would destroy any electron at those positions. DeBroglie's hypothesis was proven by experiment almost immediately. His contention that material particles could assume wave like characteristics when moving further enhanced and completed the concept of wave/particle duality which science accepts today. Science now considers the reality of matter waves whenever matter moves, but the model is only relevant at the atomic level of reality. The matter wave for a moving car or other moving macroscopic piece of matter is so negligibly small (due to the smallness of the Planck constant), that we can still use Newtonian mechanics to describe everyday motions of everyday sized objects.

However, these discoveries demonstrated that Newtonian mechanics fails miserably at the atomic level, or what is now called the quantum level, of physical reality and a new **quantum mechanics** was developed to explain these motions. Quantum mechanics is a probabilistic theory of moving particles. Because of their wave like nature, we can never know the exact position and momentum of a particle, at least not with perfect accuracy. The notion that we can never simultaneously know the position and momentum of particles with complete accuracy is called the **Heisenberg uncertainty principle**. So electrons in orbit around the nucleus are actually like probability clouds of possible positions. It is assumed in physics that electrons would appear as fuzzy particles spread out over the space occupied by the orbits, with the fixed allowable orbits representing the electron's average position during motion.

Another important principle also governs the orbiting positions of the electrons. In larger atoms that have more than one electron, the principle orbits, as defined by the principle quantum numbers in the Bohr model, are further divided into sub-orbits called orbitals. Then, according to the **Pauli exclusion principle**, only two electrons can exist in any sub-orbit or orbital. Each of the electrons in the same orbital would have a different spin, one positive and the other negative. The ground state of n = 1 can only have one orbital (the s orbital), so only two electrons with different spins can occupy the lowest energy level of any atom. The next lowest energy level, the n = 2 level or state, can be occupied by eight electrons, so it has four orbitals. The first orbital is a s orbital and then there are three higher p orbitals. Again, only two electrons with different spins can occupy any given orbital at any time. The next orbit for n = 3 can hold eighteen electrons and thus has an s orbital, three p orbitals and five d orbitals. The n = 4 energy level can hold up to thirty-two electrons and has sixteen orbitals, one s orbital, three p orbitals, five d orbitals, and seven f orbitals.

This sequence continues for even larger atoms with a greater number of electrons. Altogether then, the positions of any electron in any orbit around an atomic nucleus can be represented by a series of four quantum numbers. The first or principle quantum number gives the primary orbit. The second or orbital quantum number gives the orbital and a third or magnetic quantum number gives the orientation in a magnetic field. And finally, each electron must have a spin quantum number to completely describe its position and state of energy state relative to the atomic nucleus. Although this system may seem complicated at first, it is a very simple and logical system of classification and description. It gives science a very powerful tool for understanding the structure of the atom and how atoms react to form molecules and various chemical substances.

A historical timeline giving sequence of discoveries related to the atom can be found at www.watertown.k12.wi.us/hs/teachers/buescher/atomtime.html.

Other web pages covering atomic structure can be found at:

www.colorado.edu/physics/2000/periodic_table/atomic_structure.html

www.letsstudy.co.uk/student/gcse_science/chemistry/atomic/ index.xml

www.smartdraw.com/info/cool13.htm

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Writing assignment: Complete the 'Activities' on pages 214 and 222. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the end of week 5.

Complete the ‘Questions for Thought’ on page 230 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 5.

Complete the Group A and Group B exercises on page 230. Send the answers to the Group B exercises from one to ten to the instructor via email. Your answers are due by the end of week 5.

Lecture 11:
Nuclear Reactions

The electrons in the outermost orbits of the atom decide how an element will interact to form a molecule, but the element retains its identity as that element even when bound in the molecule. It is the composition of the nucleus that determines the identity of the element and under normal circumstances one element cannot change into another element. Chemical interactions cannot change the identity or otherwise affect the nucleus, however, certain nuclei are unstable and can undergo a process called **radioactive decay** and thereby change into other elements. This change occurs in the nucleus as the number of protons changes, an action that only occurs during radioactive decay. Radioactive decay is a spontaneous, natural and random physical process, which makes it hard to completely understand, but science has a good working model of the nucleus to help us understand its eccentricities.

The simplest nucleus is a Hydrogen nucleus that consists of just one proton. There are two other isotopes of Hydrogen, the first of which consists of a proton and neutron, called Deuterium, and the next consists of a proton and two neutrons, called Tritium. These atoms are represented by the symbols ${}^{1}_{1}H$, ${}^{2}_{1}H$ and ${}^{3}_{1}H$, where the number in the lower left corner is the atomic number, which is the number of protons, and the number in the upper left is the mass number (or atomic mass), which is the total number of nucleons. **Nucleons** are particles in the nucleus and thus the combined number of protons and neutrons. So, the mass number minus the atomic number tells how many neutrons exist in the nucleus. When the number of neutrons in the nucleus is too large relative to the number of protons, or the neutron proton ratio is too high, the nucleus is unstable and ejects particles or energy to stabilize.

The two primary material particles ejected during radioactive decay are the alpha and beta particles. The **alpha particle** is actually a high-speed helium nucleus, a combination of two protons and two neutrons, so it is very small, extremely massive and carries a double positive charge. On the other hand, a **beta particle** is a high-speed electron with a negative charge and relatively little mass. If an unstable nucleus decays by ejecting an alpha particle, the nucleus decreases by two protons, so the remaining nucleus is that of an element two places lower in the periodic table. On the other hand, a decay process proceeding by ejecting a beta goes one higher in the periodic table.

Normally, it is impossible for an electron to even exist in a nucleus. So, how can the nucleus eject an electron if there was no electron in the nucleus to begin with? The electron is actually created within the unstable nucleus by the decay of a neutron into a proton plus an electron, and then the electron is ejected. Therefore, there is one more proton in the nucleus due to the neutron decay and the new nucleus is that of an element one place higher in the periodic table. The Tritium isotope of Hydrogen is radioactive and will decay spontaneously and randomly by emitting an electron in this manner, yielding a ${}^{3}_{2}He$ nucleus, one of the isotopes of Helium.

There are 109 or more elements, each one having different isotopes and many of the isotopes are radioactive. For example, Uranium has seven different isotopes, all of which are unstable and radioactive. The two most common Uranium isotopes are ${}^{235}_{92}U$ and ${}^{238}_{92}U$, having relative abundances of 0.72% and 99.275% in naturally occurring samples. Both decay by alpha emission. The decay process of the latter can be represented by the equation

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He.$$

In this equation, the numbers of nucleons in the mass numbers on the right side (products) add up to the number of nucleons in the mother nucleus on the left. The same is true for the atomic numbers. All such nuclear equations must be balanced in this manner.

The third type of common decay yields a **gamma ray** or gamma particle. The gamma is a very high-energy photon, so the emission of a gamma during radioactive decay does not yield a different nucleus, just a less energetic nucleus of the same element. Other particles can be emitted during decay processes, but they are not as common as the alpha, beta and gamma rays. In spite of this basic understanding of the nuclear decay process, science does not have a single unique theory that explains all of the phenomena related to the nucleus. The shell theory explains some aspects of the nucleus and the fluid theory explains other aspects, but the two theories cannot presently be made into a single theory. However, we do know more about the nucleus and its internal processes than has been so far stated. The three types of radioactive decay are described at http://library.thinkquest.org/3471/radiation_types_body.html and http://www2.slac.stanford.edu/vvc/theory/nuclearstability.html.

Both of the Uranium isotopes mentioned above begin what are called **decay series**. In all, there are three such naturally occurring decay series, plus a fourth series proceeding from a human synthesized atom, Plutonium. The daughter (product) nuclei from the decayed Uranium isotopes are themselves radioactive and decay, as are their daughter nuclei and so on. Each generation of new nuclei undergoes its own decays until the final product of one or the other stable isotopes of Lead is reached. These decay processes and the decay series themselves occur over millions of years. A detailed explanation is given at http://www.mcn.net/~jimloy/decay.html .

We can measure the amount of time the decay processes take by measuring any given isotopes half-life. The decay process is spontaneous and random and we have no complete theory that allows us to predict or know when a single given isotope will decay. However, if we take a sample of the element with an extremely high number of isotopes, we can experimentally measure the amount of time that it takes half of the original sample to decay to its daughter nuclei. This time measure is called the **half-life** and it is constant for all large samples of a radioactive isotope. The half-life is a statistical quantity since it is an average of many different nuclear decay events. $^{238}{}_{92}U$ has a half-life of 4.5 billion years. So, if we start with a kilogram of $^{238}{}_{92}U$, 4.5 billion years later we will have a half-kilogram of the Uranium and a half-kilogram of its daughter. After another 4.5 billion years, we will have only a quarter kilogram of the Uranium and three-quarters kilogram of its products. This process continues, decreasing the amount of Uranium by one-half every 4.5 billion years. Not all isotopes have such long half-lives. Some can be a microsecond or less. Tritium's half-life is 12.3 years. But in each case, we have one-half of the original sample after the first half-life, one-quarter after the second half-life, one-eighth after the third half-life, and so on.

The radiation emitted during decay processes can be harmful to humans and other forms of life. If exposed to enough radiation of these types, a person can contract cancer. The radiation damages living cells by penetrating them and colliding with molecules deep within the living cells. If a gamma ray collides with a DNA molecule within the nucleus of a living cell, it can cause a mutation in the cell that can become cancerous. So science is very careful about measuring the amount of radiation that is produced by nuclear reactions as well as how much of the radiation is absorbed by human tissue. The unit of nuclear activity, measuring the radiation from nuclear reactions, is called the **curie** and equals 3.7×10^{10} nuclear disintegrations (decays) per second. On the other hand, a **rad** (short for **r**adiation **a**bsorbed **d**ose) equals 1×10^{-2} Joules of energy absorbed per kilogram of living matter. A third unit is called the **rem** (**r**oentgen **e**quivalent to **m**an). The rem accounts for the biological damage which radiation can cause. And finally, the roentgen is a purely physical unit, as is the rem, but it measures the intensity of the radioactive decay whereas the rem measures the rate of decay.

While radiation is harmful to living tissue, it is common throughout our natural environment and living beings can tolerate a small amount of radiation without any problems or health risk. In fact, there is radiation around us at all times called the **background radiation**. The background radiation comes from several sources including naturally occurring isotopes decaying underground in the earth's crust, cosmic and high-energy gamma rays colliding with air molecules in the atmosphere creating radioactive isotopes, medical x-rays and radioactive isotopes used for special medical purposes. In fact, there is a whole field of medical study called nuclear medicine. There is also a small amount of radiation in our atmosphere that has come from nuclear power plants, some by accident and some by plan when small amounts of radioactive gases are released into the atmosphere.

When an electron binds to a proton to make a neutron, part of the mass of the two particles is converted to a special type of energy called **binding energy**. Binding energy is the energy that holds the two particles together. A free neutron will decay with a half-life of about fifteen minutes, or a neutron in an unstable nucleus decays to stabilize the nucleus. No matter what the circumstances of the decay process are, the decaying neutron releases its binding energy when it decays. The binding energy in a large nucleus is even greater because there must be enough energy to overcome the repulsive forces between protons in the nucleus. No matter what the decay process, binding energy is released in one form or another during a decay process as nuclear mass is lost and converted to pure energy. Some nuclear decay processes and other nuclear reactions can release a great deal of energy, especially when they are repeated by extremely large numbers of isotopes in very short times.

It is possible to bypass the normal decay process, or rather destabilize a nucleus so that it will decay immediately, by bombarding the nucleus with a neutron or other particle. For example, ${}^{235}{}_{92}U$ normally has a half-life of several million years, but if the nucleus absorbs a free neutron it decays immediately to the ${}^{236}{}_{92}U$ isotope and again immediately into a ${}^{92}{}_{36}Kr$ (Krypton) isotope, a ${}^{141}{}_{56}Ba$ (Barium) isotope and three more neutrons. This process splits or breaks the atomic nucleus into two large nuclei, so it is commonly called atom splitting. This nuclear reaction releases a great deal of energy. If the three newly created neutrons then collide with other ${}^{235}{}_{92}U$ nuclei, even more reactions take place creating more neutrons to collide with more Uranium nuclei. The overall reaction occurs in just a few microseconds. The individual reaction is called a fission reaction or just **fission**, and when fission occurs in such a self-sustaining manner as described above, it is called a **chain reaction**. If a chain reaction of the fission process continues unchecked and uncontrolled, it is called a nuclear explosion, as in an atomic bomb. However, these reactions can be controlled and slowed down so that we can use the released energy to our benefit. In a controlled chain reaction, we use the energy to heat and vaporize water that can run a dynamo to create electricity. This is the principle behind a nuclear power plant. You can tour the United States geological Service nuclear reactor at http://geology.cr.usgs.gov/facilities/gstr/.

Fission entails the splitting of large atomic nuclei. On the other hand, very small nuclei can be smashed together to form larger nuclei in a process called **nuclear fusion**. If Tritium and Deuterium nuclei are forced together, they fuse to yield a Helium nucleus and an extra neutron, plus an extremely large amount of energy. If a large amount of these Hydrogen nuclei are forced to fuse, a process that once again occurs in mere microseconds, the resulting energy is called a thermonuclear bomb. Controlling this reaction in the way that the fission reaction is controlled could supply a great amount of energy for various uses. The basics of fusion reactors can be found at http://www.jet.efda.org/pages/content/fusion1.html.

The problem is that the positive protons in the Hydrogen nuclei repel each other by normal electrostatic forces. This means that a very large amount of energy, in the form of heat, is needed to create the conditions for the fusion reaction. The heat necessary to create fusion amounts to 60 to 100 million Kelvins at normal air pressure. The only place where such heat, or an appropriate combination of heat and high pressure, can be found in nature is the center of a star. In fact, nuclear fusion occurs in the center of all stars. The heat and energy that we receive from our sun began its journey to us from the center of the sun during a nuclear fusion process. Creating this much heat in a laboratory is nearly impossible. An atomic bomb creates enough heat to start fusion, so atomic bombs are packed in containers of Helium isotopes to create thermonuclear bombs. Controlling the energy output of fusion so it can be used in power plants is quite a different problem. Scientists are presently conducting experiments to control fusion and utilize the energy created to make electricity. They use large systems of high power lasers to create the heat necessary to start the fusion reaction and keep it going in a chain reaction of fusion. Those scientists are very near to success, which means that we may have an unlimited and cheap supply of electricity from fusion power plants in the not-to-distant future. Or, at least that is the hope.

An excellent summary of the atomic nucleus can be found at http://www.lbl.gov/abc/wallchart/chapters/02/0.html.

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Complete the 'Questions for Thought' on pages 374 and 375 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 6.

Complete the Group A and Group B exercises on page 375. Send the answers to the Group B exercises from one to ten to the instructor via email. Your answers are due by the end of week 6.

Lecture 12:

Name: ________________________ Integrated Science 101 – Final Exam

The Universe

The moon and stars in our night skies are perhaps the most prominent physical objects that we humans have ever viewed, and as such they have been central to our religious tales, folklore and scientific stories and thoughts for thousands of years. The remains of ancient stone observatories can be found in almost all pre-historic cultures, examples of which range from the pyramids in Egypt and Mexico, stone drawings of the aborigines in Australia, smaller stone towers in China, Korea, and Japan, as well as rock carvings of the American Indians. The night skies have always fascinated our people and have figured significantly in the development of science over the past few millennia.

When they viewed the night skies, ancient people perceived a stationary earth with the moon, sun and stars traveling around the earth in vast circles. Evidence that they thought the sun travels around the earth still survives in our use of the words sunrise and sunset, each implying that the sun moves and the earth is stationary. The stars occupied fixed positions relative to each other and thus inhabited the celestial sphere that orbited the earth at the greatest of possible distances. However, a few stars seemed to move relative to the greater number of fixed stars as observed over the period of many days, and these wanderers called ‘planets.’ There were five such planets, Mercury, Venus, Mars, Jupiter and Saturn, as listed according to their distances from the earth. Some of these planets also exhibited retrograde motion where they traveled forward for a period, then moved backward and again continued forward. This model formed the universe as known to humans as recently as the sixteenth century. It was called the **geocentric** system, or earth (“geos” in Greek) centered system.

One ancient Greek philosopher did offer a dissenting opinion and considered a **heliocentric**, or sun-centered, system. Helios is the Greek name of the sun. But his fellow philosophers agued that the earth could not travel around the sun or we would feel the air rushing past us as the earth moved along. So Aristarchus’ ideas remained all but forgotten for centuries. In the early 1500s an astronomer by the name of Nicholas Copernicus revived the heliocentric system and began the Scientific Revolution. He published a book proposing his theory in the 1540s, as he lay dying in his bed. In the 1590s, Johannes Kepler discovered that the Earth and planets orbited the sun in elliptical paths, not circular paths. During the next two decades, Kepler discovered mathematical methods to calculate the speed of planetary orbits and the relative distances to the planets, completing the first simple and accurate model of our planetary system.

But in the first decades of the seventeenth century, Galileo added to the human perception of the universe by turning the newly invented telescope to survey the heavens. He discovered sunspots, earthlike geology on the moon, the phases of Venus, the Great Red Spot on Jupiter, the major moons of Jupiter and the rings around Saturn. He also saw many more stars in the night sky that had been too dim to see without the aid of a telescope. With Galileo’s observations, the human perception of the universe began an expansion that has increased dramatically up to the present and still remains changing as we continue to make new discoveries. Other planets were discovered later using the telescope, first Uranus, then Neptune, and finally Pluto just seventy years ago.

Since the distances to the stars were unknown for many centuries, a different system was developed for measuring the distances between celestial objects. The Babylonians (or the more ancient Sumerians) developed the system of angular measure even before the Greek civilizations arose. They divided the circular motions in the sky into degrees, 360 degrees to be precise. The number 360 was based on the number of days in the year. This may seem strange, but 360 is an even number and it was divisible by twelve, which made it convenient for use in a twelve base system. The ancients knew there were 365 days in the year, but they considered the last five days a holiday.

We still use such arc measurement in degrees to express the relative sizes of celestial objects, as we see them. For example, both the moon and the sun have a relative size of ½ degree of arc, as observed from the earth. However, the arc size of the moon and sun does not directly tell us the actual size of the objects or the linear distances between the earth and these bodies. We now use the concept of an a**stronomical unit** (AU) to measure distances within the solar system. An **AU** is the distance between the sun and the earth. For distances to the stars and other bodies outside of the solar system, we use **light years**, which are equal to the distance traveled by light in one standard earth year, or 9.5 trillion kilometers (about 6 trillion miles).

For centuries, the fixed stars were thought too far away for their distance to be measured or calculated. Any nearby star would exhibit **parallax**, a shift in position relative to the far distant fixed stars due to the shift in observer's position as the earth orbits the sun. It was not until the middle of the nineteenth century that stars near enough to the earth (other than the sun) to exhibit parallax were discovered. We now know that there are several stars less than ten light years distance from the earth and the distance to those stars can be directly measured by parallax. Another method is needed to determine the distance to other stars.

All of these observations, both ancient and more recent, have piqued the curiosity of all who have looked on them, force us to consider the question; What is the origin of the stars, skies and the universe as a whole? The study of such questions is called cosmology, as opposed to astronomy, which is the science of observing the stars and other celestial objects. We now believe that individual stars formed from great gaseous clouds called **nebulae** (the plural form of nebula). These Hydrogen clouds slowly coalesce into great gaseous balls through gravitational attraction. These are called **proto-stars**.

Eventually, the gaseous ball of Hydrogen collapses due to gravitational attraction causing gravitational pressure at the center of the ball, which heats the central mass to the point where Hydrogen begins to fuse into Helium. When the fusion oven begins to burn, the outer pressure of escaping light energy comes to equal the inward pressure of gravitational collapse, the collapse stops and the star stabilizes into a long life of supplying light and energy to the rest of the universe. Every star consists of a **core**, the central region where the fusion engines burn, an intermediate region called the **radiation**

zone where light escapes to the surface, and finally a **convection zone** near the surface where heat is shunted to the outward by circulating convection currents, exchanging cooler gases at the surface for hotter gases far below the surface.

With this basic knowledge of how the stars shine and radiate energy, we can make extremely accurate determinations of the distance to those stars that are too far away to measure by parallax. Knowing the internal mechanics of a star, we know how bright they should be given the various characteristics of stars. In this manner we can determine the **absolute magnitude** of any star that we can see. Absolute magnitude is a measure of the **luminosity**, or amount of light that a star actually radiates. On the other hand, we can measure the **apparent magnitude** of stars, how they appear to us, through direct astronomical observations. By making a comparison of the two values, we can estimate the actual distance to stars with a high degree of accuracy.

Science can learn still more about distant stars by studying and analyzing their spectral emissions. From the spectrum of light from different stars, we can tell their surface temperatures, the relative amounts of different colors of light they emit and thus their color. With this information, we have been able to classify stars by their surface temperatures, from the hottest to the coolest, and designate them by letters of the alphabet, O B A F G K M. By taking the ratio of a star's temperature and its luminosity, it can be placed in a comparative diagram with other stars, the **Hertzsprung-Russell** or **H-R diagram**. When all known stars are placed on this diagram, we find that most stars fall in a region running from cooler stars with high absolute magnitude to hotter stars with low absolute magnitude.

All of these stars are average and belong to the **main sequence of stars**. However, other characteristic groups of stars can be identified on the H-R diagram. **Cepheid variables** are stars with variable magnitudes. They are characterized by a medium temperature and low absolute magnitude. **Red giants** are cooler stars with very low absolute magnitude, which gives them a red color and giant relative size. **White dwarfs** are medium temperature stars with high absolute magnitude. It is possible that other types of stars exist which we have not yet detected because they radiate so little light that they are not normally seen. These hypothetical stars are sometimes called brown dwarfs.

As science has learned more about stars, and classified them in this manner, we have discovered that stars go through specific life cycles. Stars are born and die. The birth of a star was described briefly above, but nothing was said of a star's later life. Our sun is a very average star, of medium temperature, size, mass and yellow color. A medium mass star will eventually burn up most of it Hydrogen producing Helium and higher elements in its core. As the star produces the elements with higher atomic numbers, it gives off less heat and radiation, destroying the delicate balance between gravitational collapse inward and radiation pressure outward. So the star begins to slowly collapse inward. At some point, the collapse rate increases to the point where the inward pressure is enough to increase the core heat once more to fuse the Helium and large nuclei and then expands outward into a red giant. Outer gases and elements are expelled and the star eventually collapses into a white dwarf.

A far more massive star would collapse more rapidly; more rapidly repressurize its core and restart its fusion engines. In the case of more massive stars, this last step leads to an explosive outburst of energy and what is called a nova, while the most massive stars create a supernova. Supernovas are rare events, while novas, or smaller exploding stars, occur more often. The vast amount of energy released by novas supernovas produces elements heavier than iron, and these elements are blown off or otherwise expelled during the explosion, becoming part of the greater universe. Elements with atomic numbers less than that of iron are produced during normal fusion reactions within stars, but all of the heavier elements were produced through explosive reactions such as that in supernovas. After shedding or blowing off their excess mass, the matter remaining in the nova collapses under gravitational attraction into either a neutron star or a pulsar. Otherwise, the remaining material in s supernova collapses to form a black hole.

A **neutron star** is so dense that a teaspoon full would weigh millions of pounds. The **pulsar** is a rapidly revolving neutron star that emits bursts or pulses of energy at regular intervals of time. The frequency of emitted radiation from a pulsar is so precise that pulsars are the most accurate natural timing devices in the universe. And finally, a **black hole** is the remnant of a star whose initial mass was sufficient enough to collapse into a small and dense enough ball that even light cannot escape the intense gravitational field generated by the black hole. A black hole is so dense and the gravitational field so strong that any material object or light wave that comes close enough would fall into the black hole and never be recovered. It is believed by some scientists that there is a black hole at the center of every galaxy, but that hypothesis has not been verified.

Ancient astronomers noted a bright band of stars stretching across the night sky. They named this bright band the Milky Way. We now know that the bright band is our own galaxy. Until about eighty years ago, the Milky Way galaxy was thought to be the whole universe. But increasing magnification in telescopes allowed astronomers to observe other distant galaxies, and science finally learned that our Milky Way galaxy was just one of billions of galaxies in the universe. A galaxy is a very large assemblage of stars. Most galaxies are spiral shaped, with two or three arms, but others galaxies can be elliptical or spherical, globular, barred or irregular. It is now estimated that there are over 200 billion galaxies in the universe, and it is believed that there are about 200 billion stars in each of the larger galaxies.

Our Milky Way galaxy looks like a long white band across the night sky because our solar system is located near the outer rim of one of the arms that forms the galaxy. So we see our own galaxy from the edge on. Our relative position in the galaxy has made it difficult to see what exists in the center of our own galaxy, so science must depend on viewing similar galaxies to understand the structure of our own galaxy. The nearest galaxy to ours is called the Andromeda galaxy, and it is on a collision course with the Milky Way although the collision will not occur for billions of years.

Like individual stars, galaxies and the universe as a whole may also have life cycles. Scientists theorize that galaxies were born by the condensation of much larger gas clouds, called proto-galaxies. The physical conditions and concentrations of the original gases and other materials that eventually formed the galaxies decide which type or shape of galaxy forms. It is also theorized that galaxies may eventually collapse into incredibly large black holes at their centers. Whole stars may eventually spiral and fall into black holes at the center of galaxies. Current theory also holds that the universe as a whole may have undergone a similar evolution. Observations in the 1920s showed that the universe is expanding. Very nearly all of the other galaxies observed by telescopes are moving away from our galaxy. We have also measured the speed with which the galaxies are moving away, and discovered that the further the distance from our galaxy, the faster the galaxies are moving away. These observations and measurements support the idea that the universe is expanding. So, if we extrapolate backwards in time, it would seem that the universe expanded from a single point billions of years in the past.

The evidence thus supports what is called the **big bang theory**. According to this theory, the whole universe was compacted into a very small point at one time, when for some unknown reason, the matter in that point exploded and eventually came to be our present universe of billions of galaxies and other celestial bodies. It is estimated that the big bang occurred 12 to 16 billion years ago. If this theory is true, it introduces three possibilities for the end of our universe. If our universe has exactly the right amount of matter, the expansion will eventually slow and stop at constant size under the action of gravitational attraction, and remain forever in a state of static equilibrium. If the total amount of matter in the universe is not enough, the pull of gravity will never be enough to stop the expansion and our universe will continue to spread out and grow forever, with the distances between stars, galaxies and black holes increasing forever. And finally, if there is enough matter in the universe to supply the gravitational force necessary to overcome the expansion, our universe will eventually collapse into a single point. This last option is called the “big crunch.” But do not worry; these events are many billions of years in the future.

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Writing assignment: Complete the 'Activities' on page 379, but conclude the activity after one week not the month that is indicated. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due by the first lecture of week 8.

Complete the ‘Questions for Thought’ on pages 403 and 404 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 7.

Find three links on the Internet that refer to any of the subjects of study above. Send the addresses of the links to the instructor along with three or four sentences explaining what you found at each of the sites. The information will be used to build a links page on the Internet for other students.

Lecture 13:
The Solar System

Our present solar system includes the sun, nine planets, an asteroid belt, moons, comets and a debris field at its very edge, left over material from the formation of the system. The discovery of all of these celestial bodies has come only in the last five centuries, and many of the discoveries have only been made since we first sent satellites and probes to investigate our star system. Our star system is called the solar system because Sol is the name of our star.

The original model of the system, dating from the time of Aristotle and the Greeks, was a geocentric model with earth at the center. Observers noticed five wandering stars, or planets, which they thought circled the earth. The planets were Mercury, Venus, Mars, Jupiter and Saturn, all named after Greek gods and goddesses. An exact mechanics of the orbiting planets, moon, sun and fixed stars was developed by Ptolemy and thus known as the **Ptolemaic system**. Plato, Aristotle's teacher, had claimed that the celestial bodies orbiting the earth did so in perfect circles because the heavens were perfect. Ptolemy took Aristotle's geocentric system and married it to Plato's circular orbits, but the system did not work accurately, so he invented the concept of an **epicycle**, a circle on a circle, to predict celestial motions, eclipses and other celestial events.

The Ptolemaic system worked well within the accuracy of observations by eyes only, and survived until the seventeenth century. But new instruments of observation that gave more accurate measurements rendered the Ptolemaic model inaccurate by the sixteenth century. Copernicus published his theory in the 1540s, literally waiting until he was dying to avoid retribution from the Catholic Church, which had built its religious universe around the Aristotelian/Ptolemaic model of the universe. The **Copernican system**, as it was known, began the Scientific Revolution that swept Aristotelian physics away over the next two centuries. The heliocentric system that Copernicus proposed was no more accurate than the Ptolemaic system because Copernicus changed the center of the system to the sun, but kept the cycles (circular orbits) and epicycles that had eventually rendered the Ptolemaic model inaccurate. In the 1590's, Kepler proposed that the planets orbited the sun in ellipses, rather than circles, which gave the first accurate model of the solar system. Even so, Kepler's model was not accepted for several more decades.

In the meantime, Kepler developed his other laws of planetary motion, which allowed scientists to calculate the variable speeds of the planets using a geometric method, and gave astronomers a mathematical method for calculating the orbital radii of the planets around the sun. In other words, **Kepler's laws of planetary** motion gave astronomers the first real model of our solar system. His model was so accurate that it can still be used today for satellites orbiting any celestial body. With this new system, the earth was no longer the center of the universe, so there were now six planets with the earth being the third from the sun. Newton's laws of motion and his universal law of gravitation merely duplicated Kepler's laws for the case of orbital motions.

Our solar system is thought to have coalesced from a gigantic cloud of Hydrogen and other elements. The various atoms in the cloud were attracted toward the middle of the cloud by gravitational action, until most of the Hydrogen in the cloud formed a large ball whose fusion engines ignited from the heat developed at the core of the ball. The light and energy fro the new sun pushed the remaining gases away leaving the heavier elements in rings around the sun which eventually coalesced in a similar manner into the planets, or so states the **protoplanet nebular model**. The new sun blew the lighter elements further away leaving heavier elements in the closest rings around it. These rings formed into the four inner planets and the lighter elements eventually formed into the five outer planets.

Today, we know of nine planets. In order from the sun outward, they are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The four inner planets that formed from the heavier elements are **terrestrial planets**, literally small rocks compared to the size of the sun and the outer planets. They are Mercury, Venus, Earth and Mars. The outer planets are more gaseous than the inner four planets. In fact, the next four planets, Jupiter, Saturn, Uranus and Neptune, are **gas giant planets**. The last planet, discovered only seven decades ago because it is so small and far away from the earth, Pluto, is a small ball of frozen gases. Between Mars and Jupiter there is a boundary between small rock planets and gas giants. The asteroid belt marks out this boundary. Asteroids are large rocks, some with diameters as large as 200 kilometers, and some as small as dust particles. It is believed that these asteroids are either a planet that never formed or the remnants of a planet that was destroyed by a gravitational tug of war by the sun and inner planets on one side and the gaseous outer planets on the other side.

The final regions in this sequence are the **Kuiper Belt** and the **Oort cloud**, vast regions lying out past the orbit of Pluto that are believed to be occupied by a mixture of rocks, frozen gases and frozen water, literally the leftovers from the formation of the solar system. The Oort cloud marks the actual boundary of the Solar system. Occasionally, a nearby star, passing planet or just simple collisions between rocks and subsequent gravitational attraction to the sun, breaks loose a big lump of material from the Kuiper Belt or the Oort cloud. This body, called a comet, then falls in toward the sun. The comet is actually a "dirty snowball," or mixture of rock, frozen gases and frozen water. As the comet falls toward the sun, the frozen gases and water are burned off leaving a tail which always faces away from the sun, even when the comet moves around the sun.

Some comets only make one pass by the sun and burn up. Others pass by once and then swing off into outer space between the stars. But a last group takes up permanent residence orbiting the sun, at least they do until they melt away after many passes by the sun. The most famous comet, Haley's comet, is known to have been passing by the earth every 70 to 75 years and orbiting the sun for more than a thousand years. It will eventually break up as its frozen gas components are burned away in passes by the sun. The comet will then leave a trail of rocks along its old permanent orbit around the sun. The earth will pass through this trail of debris and experience a shower of ‘shooting stars,’ which were once parts of the comet. We already know that there several such trails of rock debris from comets that vanished long ago, and we pass through these trails every year to see wonderful shows of ‘falling stars’ or ‘shooting stars.’

A ‘shooting star’ is not a star at all, but it was thought to be a star hundreds and thousands of years ago. It is actually what we call a **meteor** or rock which passes into or though the earth’s atmosphere. Frictional forces heat the meteor as it passes through the atmosphere at extremely high speeds. The beautiful shows of ‘shooting stars’ that we see as we pass through the trails of dead comets are actually called **meteor showers**. Most meteors burn up as they pass through the atmosphere, some bounce off the atmosphere back into space, some even explode in the atmosphere, while some land intact on the surface of the earth. The meteors that make it intact to the ground are called **meteorites**. Whatever the type, meteors are classified by their composition. They can be iron like, rocky or a combination of the two. Iron like meteors are primarily iron and nickel, while stony meteors are made of silicates and other earth like materials. Some meteorites are so small that they are no more than dust particles, called micrometeorites, and they are constantly falling to the earth, adding to the overall mass of the earth. But some meteorites are extremely large and cause a great deal of damage as they collide with the earth.

Large meteors, asteroids and sometimes comets whose masses are too large to burn off in earth’s atmosphere collide with the earth causing untold damage. The force and energy of such a collision is so great that they punch right through the crust of the earth leaving huge craters. Only a few such craters are still visible on the earth, because most have been worn away through wind and water erosion. In Arizona, the Barringer crater is still visible and it is over one kilometer wide. About 62 million years ago, one of these celestial bodies collided with the earth near the tip of the Yucatan peninsula in modern Mexico. The destruction was so great that it raised a cloud of dust covering the earth for four years (or so we estimate), blocking out the sun and cooling the surface. Many dinosaurs and plants that were not killed by the immediate explosion and collision, died in the ensuing winter like weather that prevailed over the whole earth. In fact, this collision caused the death of the dinosaurs. The part of the crater that can still be found indicates that the impact crater was nearly 200 kilometers across.

Since the space program began in The United States and Russia, a great deal of information about the planets has been gathered by space probes. Before the space program, very little was known about the planets. We now know that the surface of Mercury, which is closest planet to the sun, is pockmarked with craters like the earth’s moon. There is no atmosphere or water on Mercury, so the craters have not been eroded away as on the earth. Nor does Mercury have a moon. The surface temperature of Mercury can be as high as 427^{o}C on the side facing the sun and as low as -180^{o}Con the side away from the sun. Lead would melt on the sunny side of Mercury, so it is no wonder that there is no water or air. Mercury has a weak magnetic field and a high density, which seems to indicate that it has a molten iron core, which could be the source of its magnetic field.

Venus, the second planet from the sun, is closer to the earth in size and density than any other planet. It is also the brightest object in the night sky after the moon, and like the moon and other planets, it shines by reflected sunlight. But unlike earth, Venus is completely covered by thick dense clouds that trap heat from the sun in the Venusian atmosphere, heating the surface of the planet to 480^{o}C. The surface of Venus is hot enough to melt Lead. When a space probe was sent to investigate the surface of Venus, it was discovered that Venus rotates on its axis in the opposite direction to its rotation around the sun. All other planets rotate in the same direction as they orbit the sun. Venus is also unique because it goes through phases, relative to the earth, just like the moon's phases. The phases are characteristic of Venus' position between the earth and sun. Venus, mysteriously, does not have a magnetic field, nor does it have any moons or satellites.

Mars is farther from the sun than the earth. It is also smaller than the earth, but it has a thin atmosphere. Mars also shows evidence that there was once liquid water on the surface and perhaps there still is water beneath its surface, locked into rock formations. The surface temperatures range from moderate to cold with an average of –53^{o}C. So liquid water is impossible on the surface although pure water exists as permafrost at the north and south poles. Yet the existence of water in any form leads scientists to believe that life either exists on Mars now or existed on Mars in the distant past. Recent evidence shows that at least microscopic life existed on Mars billions of years ago, about the same time that microscopic life first evolved on the earth. Mars has an active geological system and 'Mars quakes' have been detected. It also has a weak magnetic field. Two very small moons, Deimos and Phobos, orbit Mars. In fact, they are so small that they are probably captured asteroids rather than true moons.

After Mars, the composition of the planets changes dramatically. The next planet, Jupiter, is a gas giant, so big that it dwarfs the inner planets. Jupiter mysteriously emits more energy than it reflects from the sun, so it is believed that some type of unknown energy source must be active within the planet. Jupiter also has a very strong magnetic field, which is also very unusual given that it is unlikely that Jupiter has an iron core to generate the magnetic field. Instead, it is possible that Jupiter has a core of liquid metallic hydrogen that generates its magnetic field. Jupiter may not even have a surface, as we understand the word. Instead, it may just have thicker and thicker regions of gaseous soup down to its core. The primary gases in Jupiter's atmosphere are Hydrogen and Helium. A large Red Spot rotates around the atmosphere of Jupiter just below its equator. It is probably a stable hurricane like storm that has existed for many centuries. Jupiter has sixteen moons. The four largest moons, Io, Europa, Ganymede and Callisto, are large enough to see from the earth with a small telescope. They are called the Galilean moons because they were discovered and named by Galileo.

The next planet, like Jupiter, is a gas giant and the major gases in its atmosphere are Hydrogen and Helium. It is the last of the planets that can be seen by the naked eye, without the aid of a telescope. Saturn is noted the rings that surround it. The rings of Saturn are composed of dust particles and small rocks. Saturn also has eighteen moons. The ten largest moons were first seen through telescopes, but the eight smaller moons were only discovered when space probes were sent to Saturn. The largest of Saturn's moons, Titan, is larger than Mercury and is the only moon that has its own atmosphere. Also, like Jupiter, Saturn emits more energy than can be accounted for by reflected sunlight, and it has a strong magnetic field.

The planets Uranus and Neptune are both gas giants and much further away from the sun than the other planets. The distance between Uranus and the sun is twice that of Saturn and the sun, while the distance between Neptune and the sun is three times that for Saturn. They both have very low surface temperatures, -210^{o}C and –235^{o}C, respectively, since they are so far from the sun. Both are believed to have rocky cores, surrounded by water and ice with atmospheres of Hydrogen, Helium and methane. Strangely enough, Neptune has a weather system in its atmosphere. The weather system is unusual because the earth's weather system runs on energy from the sun, but Neptune is so far from the sun that its weather system cannot run on sun energy. So the source of the energy that drives Neptune's weather system is a mystery. Uranus also has strange properties. It has a retrograde rotation and its axis of rotation lies very nearly along its plane of rotation around the sun. Uranus has rings like Saturn, but they are very narrow, and fifteen moons. Neptune also has a small system of rings and eight moons.

Pluto, the last planet, is even stranger. It is a very small frozen ball of gas, as compared with the other gaseous planets, with a single small moon called Charon. Pluto is actually smaller than the larger moons orbiting other planets. Pluto's orbit crosses Neptune's orbit, so Pluto is not really the furthest planet from the sun for the long periods of time when it is orbiting the sun inside Neptune's orbital path. The plane of Pluto's orbit is also well outside the planes of the other planets, forming a 17 degree angle with them. Recently, there has been a movement by some scientists to declassify Pluto as a planet because of the strange irregularities in its orbital path, but the majority of scientists have decided to keep Pluto as a planet.

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Complete the 'Questions for Thought' on pages 433 and 434 in writing and submit your answers to the instructor via email. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due by the end of week 7.

Find three links on the Internet that refer to any of the subjects of study above. Send the addresses of the links to the instructor along with three or four sentences explaining what you found at each of the sites. The information will be used to build a links page on the Internet for other students.

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Lecture 15:

The Earth

and

The Earth's Surface

The earth has a solid core that is mostly iron, surrounded by an outer core of molten iron and a molten magma mantle underneath the solid crust. The solid crust is the main feature with which we are familiar. The only time that humans come into contact with the molten magma from the mantle is during volcanic activity. The general features of the crust, including mountains, plains, rivers, plateaus, lakes, oceans and so on, have been the subjects of inquiry for as long as science has existed. It is only within the past few decades that science has gained any real knowledge of the earth's general makeup and this knowledge has come only through advances in technology that have allowed us to gather new data that we never before had access to. Earlier scientists were able to distinguish between the rocks and minerals that make up the crust, but could not penetrate the deeper parts of the crust, nor could they penetrate the crust itself very deeply. The **minerals** that make up the crust are naturally occurring substances or elements that form crystalline structures. On the other hand, **rocks** are congregations of one or more minerals that have been brought together in a cohesive solid form.

We have learned that the earth's crust is 46.6% Oxygen, 27.7% Silicon, 8.1% Aluminum, 5% Iron, 3.6% Calcium, 2.8% Sodium, 2.6% Potassium, 2.1% Magnesium, and 1.4% other elements. Since the crust is mostly rocks and minerals, it would be expected that the most common minerals would be those made of Silicon and Oxygen, the most abundant elements, and indeed that is the case. The two main groups of minerals are silicates and non-silicates. The **silicates** are primarily silicon oxides with other trace elements. They include the ferromagnesian silicates, which contain traces of iron and/or magnesium, the nonferromagnesian silicates, which includes quartz and silicon oxides with other trace elements, and the clay minerals.

Of all the various minerals in the earth's crust, quartz is the most common. Quartz can assume several different crystalline forms or the principle mineral in different types of rocks. The nonsilicate minerals contain compounds of the other common elements found in the crust. They principle groups in this category are the carbonates, oxides, phosphates, sulfates, sulfides, halides and the native elements, which are pure elements. Examples of the native elements are silver and gold, which appear in veins, sulfur which is deposited by volcanic action and carbon. Just as quartz can crystallize in different forms, carbon can also appear in different crystal structures. In one form, carbon appears as diamonds, the hardest of the known natural materials. But Carbon can also appear as graphite, like that used in pencils, or even as Bucky balls, a soccer ball like structure with special properties. The specific form that carbon takes upon crystallization depends upon the physical conditions at the time of crystallization. The same is true of all crystals as well as rocks.

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When the rest of the earth is taken into consideration, the makeup changes a bit from the crust alone. At 29.8% Oxygen is no longer the most abundant element, that distinction goes to Iron at 33.3%. Next comes Silicon at 15.6%, followed by Magnesium at 13.9%, Nickel at 2%, Calcium at 1.8%, Aluminum at 1.5%, and Sodium at 0.2%, while all of the other elements make up only 1.9% of the earth's total weight. Iron contributes the greatest amount to the weight of the earth because the inner and outer core of the earth are primarily Iron.

Rocks are classified according to their origin. The three classifications for rocks are igneous, sedimentary and metamorphic. A **rock** differs from a mineral in that substances are chemically bound to form, while minerals are physically bound together to form rocks. **Igneous rocks** are formed by fire (from the Latin 'ignis'), tempered by the heat within the earth. All rocks were igneous at one time, cooling and solidifying from the primordial ball of molten material that formed the earth. **Sedimentary rocks** form from particles or materials dissolved or suspended in water that collect over long periods of time and solidify. And finally, **metamorphic rocks** form from previously existing rocks that are altered, or undergo metamorphosis, by heat or pressure to form new and different rocks. Metamorphic rocks are usually formed when older rocks are pushed deep under the surface within the crust where heat and pressure can alter them.

Geology would be simple if the surface were static and unchanging, but the surface of the earth is constantly changing with new rocks being formed as old rocks undergo the processes of weathering and erosion, subduction and uplifting, to mention only a few of the geological processes that affect the surface of our planet. New rocks are formed by magma coming to the surface and solidifying on cooling. Erosion breaks the new igneous rocks down into small particles called sediment, which are carried to rivers, lakes, and seas where it settles to the bottom and eventually becomes a new generation of sedimentary rocks. In some cases, the sedimentary rocks are forced deep underground where the internal heat escaping from the core warming as well as the crushing weight of the surface above make new metamorphic rocks. Older metamorphic rocks and igneous rocks can also be forced down deep into the crust and change into new rocks, but they all may be forced even further downward where they could melt and become magma once more to start the process all over. This complete process of birth, alteration and rebirth of rocks is called the rock cycle and the story of how it occurs is the key to understanding the other mechanisms of geology.

The earth's inner core is estimated to be at least 6000^{o}C. That heat must escape and dissipate outward through the mantle and the crust. The **core** is thought to be solid, even though it is much hotter than the metals of which it is composed, with a diameter of 6,940 kilometers. But the pressures are so great at the core that they force the metals into the solid state in defiance of the heat The pressure is not great enough to overcome the heat in the outer core, which surrounds the inner core, so the metals are liquefied or molten in the outer core. The heat from the core continues outward as it dissipates and heats the layer of rock building material, or magma, that it next encounters. This layer is called the **mantle**. The mantle is 2870 kilometers thick. By the time the heat dissipates outward to the **crust**, it is not intense enough to keep the magma molten, and rock and minerals begin to form. The layer between the hot mantle and the crust is called the **Mohorovicic discontinuity** or the **Moho** for short.

Within another context, it is useful to look at the fluidity of the materials in these upper layers of the earth's body. Scientists learn about these unseen regions in the earth by gauging and measuring seismic and other waves traveling through the earth. The two primary seismic waves, S-waves and P-waves, have different characteristics and travel through different media differently. It is a simple matter to find boundaries between regions where the waves either reflect or refract, and to discover the chemical characteristics of rock or magma by the speeds of waves through the regions. We have also learned that there is a hot, semi-fluid elastic region, called the **asthenosphere**, at a depth of 130 to 160 kilometers below the earth's surface. A solid region called the **lithosphere**, which includes the entire crust, floats on top of the semi-fluid asthenosphere. The situation presented by the relationship between these two regions is called plate tectonics, a successful theory which is only three decades old.

At the end of the first decade of the twentieth century, Alfred Wegener noticed that the major continents looked as if they were giant pieces of a puzzle that could be placed together to form one large continent. He then proposed that the continents were indeed joined into a single super continent, Pangaea, in the distance past and had drifted apart. His theory was discarded shortly thereafter, and ignored until the 1960s when new evidence proved the truth of his hypotheses. But the continents do not drift on the oceans, like giant islands, as he thought. Instead, the continents form large crustal plates that ride on top of asthenosphere. Evidence for this notion came from the discovery that a large north to south crack in the earth follows along the middle of the Atlantic Ocean. On either side of this crack, called the **Mid-Atlantic Ridge**, the earth's crust moves away from the crack. This action is called **sea-floor spreading**. As the ocean floor plates spread apart at the Mid-Atlantic Ridge, magma comes to the sea floor from the mantle, replacing the moving crust with newly formed crust. The sea floors are actually the newest part of the earth's crust, and the continents are the oldest.

With the Atlantic Ocean growing wider in this manner, the continents are closing in on the Pacific Ocean, which is growing smaller. The Pacific Ocean is growing smaller as the continents ride up over its edge forming **subduction zones.** The Pacific plate dips down into the mantle and melts away along these zones. At places where the Pacific floor crust rides down under a continental plate, the continental plate rises up forming mountain chains such as the Andes in South America. On the ocean side of the subduction zone, paralleling the Andes Mountains, we have the Mariannas **oceanic trench**, which is the deepest place in all the oceans of the earth. In other locations, two continental plates can collide, as in the case of the Indian Subcontinent and Asia, causing the continents to rise where they meet. An ongoing collision of this type formed the Himalayan Mountains millions of years ago. The Ural Mountains that form the boundary between Europe and Asia formed from the same type of collision hundreds of millions years ago. The whole rim of the Pacific Ocean is a collision zone of one type or another, which causes severe earthquakes and volcanoes. The presence of so many volcanoes and earthquakes has given the Pacific Rim the nickname of the Ring of Fire. Similar areas exist throughout the earth, explaining the origins of many mountain ranges and other geological details of the earth's crust. This whole theory is called **plate tectonics**, and it has revolutionized the study of geology in the last few years.

With the continents moving in different directions, there are great amounts of pressure within the crustal plates that form the continents. Smaller cracks have formed in portions of the crust where the pressures have been great enough to cause slippage between different portions of the crust. These cracks are called **faults**, and they mark the boundaries between portions of the crust that move relative to each other. These movements or shifts in the crust are the primary cause of earthquakes. But the **stresses** (applied forces and pressures) and **strains** (the reaction of material to the stress) in the crust do not always lead to the formation of faults. In many cases the stresses lead to **folds** and bends in the rock. Although the rock which makes up the crust is solid, under great amounts of stress applied over very long periods of time, the solid rock can actually display some plasticity and bend. Some of the resulting folds are small and can be seen wherever a hill or small mountain has been cut away, for example along a road or highway. A fold curving upward is called an **anticline** and a fold curved downward is a **syncline**.

In other cases, the folding can occur over vaster areas of surface and create new mountain ranges from surface that was once flat. The lower hills and mountains in Southeastern Ohio and West Virginia are ancient seabeds, formed of sedimentary rocks, which have been rippled, folded and uplifted by stresses within the crust. Weathering has worn away the softer materials and left the hills and mountains as we now find them. The three basic origins of mountains are folding, faulting and **volcanoes**. Once a mountain or a mountain range is built by nature, it immediately begins to weather, eventually forming the surface features that we now find. **Weathering** can take two forms, chemical and mechanical. Chemical weathering occurs when rocks and minerals react chemically to water, gases, the atmosphere or solutions. Mechanical weathering occurs when rocks break down into smaller and smaller pieces by mechanical action such as wind or water erosion. **Frost wedging**, when water freezes between rocks and spreads them apart, then thaws and freezes again, widening fissures and cracks in rocks, is an important form of weathering in colder mountain regions. Even plants and trees add to weathering when their roots grow into cracks in rock and widen the cracks, making the rocks more susceptible to break down by wind and water action.

Water eventually carries the smaller broken rocks and sediment downward to be deposited elsewhere and form new land or, when mixed with dead plant and animal material and bacterial action, form new soil. Sediment and small rocks will be deposited by water wherever fast running water slows down. The more water slows, the greater the amount of sediment deposited. When rain causes a river to overflow its boundaries, the water of the flooded river slows and carries sediment over its **floodplain** where the sediment is deposited. The Ancient Sumerian civilization grew up on the floodplains between the Tigris and Euphrates rivers, and the ancient Egyptian civilization evolved along the floodplains of the Nile River. Small streams with fast moving water carry sediments down from the mountains to the valleys below. When the streams slow down in the valleys or plains between the mountains they deposit the sediment they carry, filling in the valleys between the mountains. And when it rains heavily, smaller streams flow to larger rivers, which carry sediment to lakes or larger bodies of water. The water in rivers slows tremendously upon entering large bodies of water, depositing their sediments and forming deltas. One of the more famous deltas, the Mississippi Delta, occurs where the Mississippi River flows into the Gulf of Mexico and deposits sediment and silt from all over central North America.

Glaciers are another important factor to consider in geological matters. A **glacier** is a large mass of ice that has formed over land. Glaciers can actually move under their own weight. Continental glaciers are presently located over the Arctic and Antarctic regions of the earth. During the ice age that ended several thousand years ago, huge continental glaciers covered much of North America, Europe and Northern Asia. These glaciers pushed rock in front of them as they moved forward, they picked up rocks and deposited them in different places when they melted, and their great weight left depressions in softer rock that became lakes when the glaciers eventually melted. The Great Lakes of North America were formed in this manner. Smaller glaciers now exist in cold mountainous regions of the world. They generally form between mountains and are usually called alpine glaciers or valley glaciers. As such glaciers move through the v-shaped valleys between mountains, they scoop out material, widening and deepening the valleys. These last processes are very lengthy processes that occur over thousands and hundreds of thousands of years. Many of the processes that shape our surface are extremely slow processes requiring millions of years, so an individual would see very little change in a landscape over a single lifetime and perhaps never know the forces that are at work in nature.

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Writing assignment: Complete the 'Activities' on pages 468, 469,470, 492 and 506. Write a report about your results, making it as complete as possible, and send a copy of your written work to the instructor via email attachment. The report is due as soon as possible before the final exam.

Complete the ‘Questions for Thought’ on pages 485 and 486, and through 31 on pages 525 and 526. The best answers will be posted over the Internet for further discussion by the whole class. Your answers are due as soon as possible before the final exam.

INSTRUCTIONS
Exam #1 – Chapters 1-6

Exam #1 must be submitted no later than Friday, 15 June 2002, Midnight (Singapore time). Please complete the exam yourself. This gives you four days to finish the exam. You are not allowed to share your work with other students or get answers from other students or friends. However, you may use your textbook for the appropriate equations and numerical constants as they are need to complete the problems.

1. The "scientific method" is (a) a continuing process, (b) a way to arrive at ultimate truth, (c) a laboratory technique, or (d) based on accepted laws and theories.
2. A scientific law or theory is valid (a) forever, (b) for a certain number of years, after which it is retested, (c) as long as a committee of scientists says so, or (d) as long as it is not contradicted by new experimental findings.
3. A hypothesis is (a) a new scientific idea, (b) a scientific idea that has been confirmed by further experiment and observation, (c) a scientific idea that has been discarded because it disagrees with further experiment and observation, or (d) a group of linked scientific ideas.
4. Which of the following quantities is not a vector quantity? (a) velocity, (b) acceleration, (c) mass, or (d) force.
5. An object falls under the force of gravity in free fall. Neglecting air resistance, how far will it fall in 3.5 seconds? ______________ meters .
6. Two objects have the same size and shape but one of them is twice as heavy as the other. They are dropped simultaneously from a tower. If air resistance is negligible, (a) the heavy object strikes the ground before the light object, (b) they strike the ground at the same time, but the heavy object has a greater speed, (c) they strike the ground at the same time and have the same speed, or (d) they strike the ground at the same time, but the heavy object has a lower acceleration because it has more mass.
7. In order to cause something to move in a circular path, it is necessary to provide (a) a reaction force, (b) an inertial force, (c) a centripetal force, or (d) a gravitational force.
8. Of the following, the longest is (a) 1000 ft, (b) 500 m, (c) 1 km, or (d) 1 mi.
9. How long does a car whose acceleration is 2 m/sec^2 need to go from 10 m/sec to 30 m/sec? (a) 10 sec, (b) 20 sec, (c) 40 sec, or (d) 400 sec.
10. A woman whose mass is 60 kg on the earth's surface is in a spacecraft at an altitude of one earth's radius above the surface. Her mass there is (a) 15 kg, (b) 30 kg, (c) 60 kg, or (d) 120 kg.
11. A box weighs 3 pounds. Its mass is (a) 0.31 kg, (b) 1.36 kg, (c) 6.6 kg, or (d) 29.4 kg.
12. Show from the defining formula that the unit of centripetal force is the Newton.
13. A person stands on a scale in an elevator. When the elevator is at rest, the scale reads 800 N. When the elevator starts to move, the scale reads 600 N. The elevator is moving (a) up with an acceleration of 2.45 m/sec^2, (b) down with an acceleration of 2.45 m/sec^2, (c) up with an acceleration of 9.8 m/sec^2, or (d) down with an acceleration of 3.27 m/sec^2
14. An object that has linear momentum must also have (a) acceleration (b) angular momentum, (c) kinetic energy, or (d) potential energy.

15. Two balls, one of mass five kilograms and the other of mass 10 kg, are dropped simultaneously from a window. When they are 1 meter above the ground, the balls have the same (a) kinetic energy, (b) potential energy, (c) momentum, or (d) acceleration.
16. The work done in holding a 50 kg object at a height of 2 m above the ground for 10 sec is (a) 0, (b) 250 Joules, (c) 1000 Joules, or (d) 98,000 Joules.
17. A 40 kg boy runs up a flight of stairs 4 m high in 4 sec. His power output is (a) 160 Watts, (b) 392 Watts, (c) 40 Watts, or (d) 1568 Watts.
18. A 1 kg object has a potential energy of 1 joule relative to the ground when it is at a height of (a) 0.102 meters, (b) 1 meter, (c) 9.8 meters, or (d) 98 meters.
19. If the speed of a moving car is doubled, say from 30 to 60 km/ hr, its kinetic energy will (a) be the same, (b) be ½ of the original, (c) also double, or (c) be four times greater.
20. Absolute zero may be regarded as that temperature at which (a) water freezes, (b) all gases become liquids, (c) all substances become solids, or (d) molecular motion in a gas would be the minimum possible.
21. On the molecular level, heat is (a) kinetic energy, (b) potential energy, (c) rest energy, or (d) all of the above in proportions that depend on the circumstances.
22. No engine can be 100% efficient because there will always be energy loss (heat that is not converted to work) due to (a) colder surroundings, (b) friction, (c) entropy, or (d) mechanical failure.
23. Which of the following statements is NOT correct? (a) matter is composed of tiny particles called molecules, (b) These molecules are in constant motion, even in solids, (c) All molecules have the same size and mass, or (d) The differences between the solid, liquid and gaseous states of matter lie in the relative freedom of motion of their perspective molecules.
24. The heat a refrigerator absorbs from its contents is (a) less than it gives off, (b) the same amount it gives off, (c) more than it gives off, or (d) any of the above depending on the design.
25. The greater the entropy of a system of particles, (a) the less the energy of the system, (b) the more the energy of the system, (c) the more the order of the system, or (d) the less the order of the system.
26. Lead melts at 330 degrees C. On the absolute scale this temperature corresponds to (a) 57 K, (b) 362 K, (c) 571 K, or (d) 603 K.
27. A heat engine absorbs heat at a temperature of 127^{o}C and exhausts heat at a temperature of 77^{o}C. Its maximum efficiency is (a) 13%, (b) 39%, (c) 61%, or (d) 88%.
28. How much energy is required to change 50g of ice at 0^{o}C to water at 20^{o}C? (a) 4 kJ, (b) 17kJ, (c) 19 kJ, or (d) 21 kJ.
29. How many kJ of heat are required to raise the temperature of 200 g of water from 20^{o}C to 100^{o}C? (a) 32 kJ, (b) 67 kJ, (c) 117 kJ, or (d) 327 kJ.
30. The distance from crest to crest of any wave is called its (a) frequency, (b) wavelength, (c) speed, or (d) amplitude.
31. Sound waves are (a) longitudinal, (b) transverse, (c) a mixture of longitudinal and transverse, or (d) sometimes longitudinal and sometimes transverse.
32. Sound waves travel faster in (a) air, (b) water, (c) iron, or (d) a vacuum.

33. Sound waves cannot travel through (a) a solid, (b) a liquid, (c) a gas, or (d) a vacuum.
34. The higher the frequency of a wave traveling in a given medium (a) the lower its speed, (b) the shorter its wavelength, (c) the smaller its amplitude, or (d) the lower its pitch.
35. Diffraction refers to (a) the bending of a wave around an obstacle in its path, (b) the bending of a wave as it moves from one medium into another, (c) the bouncing of a wave off of a surface, or (d) the constant speed of a wave as it travels in a straight line.
36. Waves in a lake are observed to be 5 m in length and to pass an anchored boat 1.25 sec apart. The speed of the waves is (a) 0.25 m/sec, (b) 4 m/sec, (c) 6.25 m/sec, or (d) impossible to calculate from the information given.
37. If the velocity of sound is 331 m/sec in air at 0^{o}C, the velocity of sound on a hot day with an air temperature of 35^{o}C will be ___________m/sec.
38. Find the frequency of sound waves in air whose wavelength is 25 cm. Use 343 m/sec as the speed of sound in this example. (a) 975 Hz, (b) 1372 Hz, (c) 1777 Hz, or (d) 2012 Hz.
39. An automobile sounding its horn is moving away from an observer. The pitch of the horn's sound relative to its normal pitch is (a) higher, (b) lower, (c) the same, or (d) higher or lower depending upon the exact frequency.
40. A pure musical note causes a thin wooden panel to vibrate with the same frequency. This is an example of (a) an overtone, (b) diffraction, (c) resonance, or (d) interference.

1. How does an electron acquire an electric charge? (a) from an imbalance of subatomic particles, (b) by induction or contact with charged bodies, (c) by the friction of certain objects rubbing together, or (d) charge is a fundamental property of an electron.

2. In an electric current, electrons are moving (a) at a very slow rate, (b) at the speed of light,
(c) faster than the speed of light, (d) at a speed described as "Warp 8."

3. A permanent magnet has magnetic properties because (a) the magnetic fields of its electrons are balanced, (b) of an accumulation of monopoles in the ends, (c) the magnetic domains are aligned, or (c) All of the above are correct.

4. If you reverse the direction that a current is running in a wire, the magnetic field around the wire (a) is oriented as it was before, (b) is oriented with an opposite north direction, (c) flips to become aligned parallel to the length of the wire, or (d) ceases to exist.

5. A step-up transformer steps-up or increases (the) (a) power, (b) current, (c) voltage, or (d) all of the above are correct.

6. An electric current through a wire is 8.00 Coulombs every 2.00 seconds. The magnitude of the current is (a) 1/4 Amp (b) 1 Amp, (c) 4 Amps, or (d) 8 Amps.

7. A small radio operates on 3.00 Volts and has a resistance of 15.0 Ohms. At what rate does the radio use energy? (a) 0.4 Watts, (b) 0.6 Watts, (c) 0.8 Watts, or (d) 1.2 Watts.

8. According to the electromagnetic wave model, visible light is produced when (a) an electric charge is accelerated with a magnitude within a given range, (b) an electric charge is moved at a constant velocity, (c) a blackbody is heated to any temperature above absolute zero, or (d) an object absorbs electromagnetic radiation.

9. The ratio of the speed of light in a vacuum to the speed of light in some transparent materials is called (a) the critical angle, (b) total internal reflection, (c) the law of reflection, or (d) the index of refraction.

10. Any part of the electromagnetic spectrum, including the colors of visible light, can be measured in units of (a) wavelength, (b) frequency, (c) energy, or (d) any of the above.

11. Light moving through a small pinhole does not make a shadow with a distinct, sharp edge because of (a) refraction, (b) diffraction, (c) polarization, or (d) interference.

12. Max Planck made the revolutionary discovery that the energy of vibrating molecules in blackbody radiation existed only in (a) multiples of certain fixed amounts, (b) amounts that smoothly graded one into the next, (c) the same, constant amount of energy in all situations, or (d) amounts that were never consistent from one experiment to the next.

13. Today, light is considered to be (a) tiny particles of matter that move through space, having no wave properties, (b) electromagnetic waves only, with no properties of particles, (c) a small-scale phenomenon without sharp distinction between particle and wave properties, or (d) something that is completely unknown.

14. An x-ray is really (a) a high-speed helium nucleus, (b) the same as a beta ray, (c) a high-energy photon, or (d) a high-speed electron.

15. The speed of light traveling through a substance with the index of refraction of 1.5 is (a) $1\text{x}10^{8}$ m/sec, (b) $2\text{x}10^{8}$ m/sec, (c) $3\text{x}10^{8}$ m/sec, or (d) $4\text{x}10^{8}$ m/sec.

16. The energy of a gamma photon with a frequency of $5.00\ \text{x}10^{20}$ Hertz is (a) $2.8\text{x}10^{-19}$ Joules, (b) $3.1\text{x}10^{-19}$ Joules, (c) $3.3\text{x}10^{-19}$ Joules, or (d) $4.1\text{x}10^{-20}$ Joules.

17. An Ultraviolet photon has a wavelength of 135 nanometers (nano=10^{-9}), so it would have an energy of ________Joules.

18. Most of the mass of an atom is concentrated in (a) the nucleons, (b) the orbiting

electrons,
(c) electrons in the nucleus, or (d) orbiting protons.

19. In the final quantum mechanical analysis, an electron orbiting the a nucleus in the atom is
(a) a small solid particle moving at nearly the speed of light, (b) a cloud of probability spread across the orbit, (c) spinning or hovering about a single spot in the orbit, or (d) non-existent.

20. The maximum number of electrons that can occupy an orbital or sub-shell in an atom is (a) one, (b) two, (c) three, or (d) four.

21. A photon with the most energy would be in the range of (a) red light, (b) orange light, (c) green light, or (d) blue light.

22. According to the Bohr model of the atom, an electron gains or loses energy only by (a) moving faster or slower in an allowed orbit, (b) jumping from one allowed orbit to another, (c) being completely removed from an atom, or (d) jumping from one atom to another.

23. The Bohr model of the atom described the energy state of electrons with one quantum number. The present quantum mechanics model uses how many quantum numbers to describe the energy state of an orbiting electron? (a) one, (b) two (c) three, (d) four, (e) eight, or (e) ten.

24. The space in which it is probable that an electron will be found is described by a/an (a) circular orbit, (b) elliptical orbit, (c) orbital, or (d) geocentric orbit.

25. The nucleus of the element cadmium ($^{112}{}_{48}Cd$) is made up of (a) 48 protons and 112 neutrons, (b) 64 protons and 48 neutrons, (c) 48 nucleons, or (d) 48 protons and 64 neutrons.

26. A Palladium atom has an atomic number of 46, therefore it would normally have ________ electrons orbiting the nucleus.

27. In a gamma decay, the remaining element (the daughter) is (a) the same, (b) one higher in the atomic chart, (c) one lower in the atomic chart, (d) two higher in the atomic chart, or (e) two lower in the atomic chart.

28.An element has a half-life of 120 days. Therefore, after one year, there will only be about ---
(a) one-half, (b) one-quarter, (c) one-eighth, (d) one-sixteenth, or (e) one-thirty second ---
of the original element left.

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29. The strongest of the four natural forces or interactions is while the weakest is ________________________ . [electromagnetism, strong nuclear, weak nuclear, friction, gravitation, wind resistance, radioactive decay]

30. All of the energy of the sun, and of all stars, is produced by (a) radioactive decay, (b) nuclear fusion, (c) nuclear fission, or (d) highly volatile burning gases.

31. Which element has the highest binding energy per nucleon, which means that no larger nuclei can be made by fusion and still give off energy? (a) lead, (b) magnesium, (c) iron, or (d) radium.

32. A chain reaction in the fission process can be controlled, as in a nuclear power plant, by (a) a moderator absorbing extra neutrons, (b) using more highly enriched uranium, (c) using plutonium instead of uranium, or (d) drawing more energy off by boiling more water to generate electricity.

33. The type of element is determined by the number of (a) nucleons, (b) protons, (c) electrons, or (d) neutrons.

34. If we have two atoms of the same element, but they have different masses due to extra neutrons in the nucleus, we would say that they are different (a) isotopes, (b) isotones, (c) decays, or (d) ions --- of the same element.

35. All elements that are more massive than iron were formed in a (a) nova, (b) white dwarf,
(c) supernova, or (d) black hole.

36. Our solar system and thus the earth are located in (a) the Andromeda galaxy, (b) a globular cluster, (c) the Great Nebula in Orion, or (d) the Milky Way galaxy, or (e) the Crab Nebula.

37. Whether the universe will continue to expand or will collapse back into another big bang seems to depend on what property of the universe? (a) the density of matter in the universe, (b) the age of galaxies compared to the age of their stars, (c) the availability of gases and dust between the galaxies, or (d) the number of black holes.

38. The star Polaris is very nearly above the north celestial pole and nearby appear to move __?__ relative to Polaris? (a) straight by, (b) with a looping motion, (c) counterclockwise, or (d) clockwise.

39. If the core remaining after a supernova has a mass between 1.5 and 3 solar masses, it collapses to form a (a) white dwarf, (b) neutron star, (c) red giant, or (d) black hole.

40. The Earth moves the slowest in its orbit during the month of (a) January, (b) March, (c) July, or (d) September.

41. The Earth, other planets, and all members of the solar system (a) have always existed, (b) formed thousands of years ago from elements that have always existed, (c) formed millions of years ago, when the elements and each body were created at the same time, or (d) formed billions of years ago from elements that were created in many previously existing stars.

42. A small body that falls from space to the surface of the earth is a (a) meteoroid, (b) meteor, (c) meteor shower, or (d) meteorite.

43. A body which normally orbits the sun in very irregular or highly elliptical orbits and is know as a dirty snow-ball (made of a mixture of dirt, gravel and ices) is called a/an (a) asteroid, (b) comet, (c) moon, or (d) Oort cloud.

44. Our sun is (a) too large to ever become a supernova, (b) too small to evolve into a white dwarf, (c) destined to become a black hole, or (d) too small to ever become a supernova.

45. Most stars (a) are red giants, (b) belong to a class of stars called brown dwarfs, (c) are white dwarfs, or (d) are classified in the main sequence of stars.

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In alphabetical order, the planets are
Earth, Jupiter, Mars, Mercury, Neptune, Pluto, Saturn, Uranus and Venus.

46. Which four planets form the inner rocky part of the solar system: _________ , ,
__________ , ___________ .

47. Which three planets are gas giants: _________ , __________ , __________ .

48. Which planet revolves around the sun well outside of the plane or disk of the other planets and crosses the orbital path of another planet so that it is sometimes closer to the sun than the other planet: ____________ .

49. Which planet has nearly the same mass as the earth, has a very thick cloud cover, and has a surface temperature which is hot enough to melt lead: __________ .

50. Which planet is the largest according to its volume: ___________ .

51. Which planet goes through phases, just like the earth's moon: ___________ .

52. The planet (other than earth) which is most likely to harbor life is __________ .

53. Because of the Coriolis effect, winds in the northern hemisphere are deflected in which direction? (a) clockwise, (b) up, (c) counterclockwise, or (d) down.

54. The seasons are caused by (a) the tilt of the earth's rotational axis, (b) how close the earth is to the sun, (c) sunspots, or (d) ocean currents.

55. The earth's tides are caused primarily by (a) the spinning motion of the earth, (b) the gravitational pull of the moon, (c) the gravitational pull of the sun, or (d) plate tectonics.

56. A lunar eclipse does not occur every month because (a) the plane of the moon's orbit is inclined to the elliptic, (b) of precession, (c) Earth moves faster in its orbit when it is closest to the sun, or (d) Earth's Axis is tilted with respect to the sun.

57. High tides will normally occur how many times a day at any point of the earth? (a) once, (b) twice, (c) three times, (d) five times.

58. A solar eclipse occurs during those occasions when what other body lies on a direct line between the earth and the sun? (a) Halley's comet, (b) Mars, (c) Venus, or (d) the moon.

59. The Earth's CRUST is primarily made of (a) iron, (b) ferromagnetic materials, (c) silicates and other minerals, or (d) aluminum ores.

60. Which of the following is NOT one of the three basic classes of rock: (a) igneous,

(b) volcanic, (c) metamorphic, or (d) sedimentary.

61. The primary cause of earthquakes is (a) volcanic activity, (b) movement of tectonic plates,
(c) asteroid collisions with the earth, (d) magnetic pole shifts.

62. The central CORE of our planet Earth is generally thought to be made of (a) rock, (b) ice,
(c) magma, or (d) iron.

63. The Mohorovicic discontinuity lies along the boundary between the earth's (a) crust and core, (b) crust and mantle, (c) mantle and core, or (d) the inner and outer cores.

64. Ocean-floor spreading was first detected with the discovery of (a) the mid-Pacific ridge,
(b) the Ring of Fire, (c) the North American tectonic plate, or (d) the Mid-Atlantic Ridge.

65. The youngest part of the earth's rock crust can be found (a) on the ocean floor, (b) in the Himalayan mountains, (c) in the continental plates, or (d) in Antarctica.

66. On the Richter scale, an 8.0 earthquake would be how many times stronger than a 5.0 earthquake? (a) ten, (b) one hundred, (c) one thousand, (d) ten thousand, or (e) 100 thousand.

67. The rim of the Pacific Ocean where most earthquakes and volcanoes occur is called the
(a) Marianas trench, (b) shadow zone, (c) Mohorovicic discontinuity, or (d) Ring of Fire.

68. Which of the following statements about the moon in NOT true: (a) The moon has no atmosphere, (b) The geology of the moon exhibits plate tectonic movements, (c) The moon is cold such that it exhibits no volcanic action, or (d) The youngest rock on the moon's surface is three billion years old.

69. The portion of the earth which contains molten rock, is called the (a) crust, (b) inner core,
(c) outer core, or (d) mantle.

70. The most common element in the earth's crust is (a) oxygen, (b) silicon, (c) carbon, or (d) iron.

71. The most common mineral in the earth's crust is (a) carbon dioxide, (b) iron oxide,
(c) silicon dioxide, or (d) aluminum dioxide.

72. The most common element in the earth's atmosphere is (a) hydrogen, (b) helium,

(c) nitrogen, or (d) oxygen.

73. The least dense rocks are found in (the) (a) continental crust, (b) oceanic crust, (c) neither, since both are the same density.

74. Rocks making up the ocean basins and much of the earth's interior have the same chemical composition as (a) granite, (b) basalt, (c) halite, or (d) water.

75. The presence of an oceanic trench, a chain of volcanic mountains along the continental edge, and deep-seated earthquakes is characteristic of a/an (a) ocean-ocean plate convergence, (b) ocean-continent plate convergence, (c) continent-continent plate convergence, or (d) none of the above are correct.

76. The preferred name for the very large ocean waves that are generated by an earthquake, landslide, or volcanic explosion is (a) tidal wave, (b) tsunami, (c) tidal bore, or (d) Richter wave.

77. The modern theory which explains mountain building in cases like the Himalayas, the Andes and the Urals is called (a) continental drift, (b) volcanic activation, (c) Uniformitarianism, or (d) plate tectonics.

78. The center or point underground where an earthquake occurs is called the (a) focus, (b) fault scarp, (c) escarpment, or (d) elastic boundary.

79. The primary cause of earthquakes is (a) volcanic activity, (b) movement of tectonic plates,
(c) asteroid collisions with the earth, (d) magnetic pole shifts.

80. We have detected the inner structure of the Earth by closely monitoring (a) s and p waves,
(b) d and f waves, (c) sound and light waves, or (d) solid rock and ocean waves.

81. Ocean-floor spreading was first detected with the discovery of (a) the mid-Pacific ridge,
(b) the Ring of Fire, (c) the North American tectonic plate, or (d) the Mid-Atlantic Ridge.

82. The youngest part of the earth's rock crust can be found (a) on the ocean floor, (b) in the Himalayan mountains, (c) in the continental plates, or (d) in Antarctica.

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83. Explain the ultimate source of the energy in all nuclear reactions:

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84. Explain what a light wave is:

85. Explain the scientific theory of the origin of the universe:

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Electricity: $I = q/t$ $P = IV$ $V = IR$ $V_p/N_p = Vs/Ns$ $V_pI_p = VsIs$

Light: $n = c/v$ $c = 8f$ $c = 3 \times 10^8$ m/sec $E = hf$ $h = 6.63 \times 10^{-34}$ J·sec

Nuclear reactions: $k = rate/n$ $t_{1/2} = 0.693/k$ $E = mc^2$