PHY 111
Course Number

Physical Science Concepts
Course Title

Science Division

3 Credits
2 Class Hours/Week
2 Laboratory Hours/Week

Required Texts:
Bragg, Melvin
On Giants’ Shoulders: Great scientists and Their Discoveries
John Wiley & Sons 1998

Alfare, Carlo
Physical Science Concepts: Course and Laboratory Manual
MCCC, 8th Edition

14 Weeks
Length of Semester

Week 15
Final Examination

Catalog Description:
A survey of fundamental ideas in the physical sciences, appropriate for students not majoring in science, mathematics or engineering. Attempts to establish a broad awareness of the evolution and present scope of human knowledge of the physical world focusing on nature's basic forces and structures. Emphasis is given to technological applications of knowledge, and to social concerns generated by scientific progress. Topics include: measurement, motion, forces, (gravitational, electromagnetic, and nuclear), astronomy, light, sound, atomic structure, molecular structure, crystal structure, nuclear structure, and numerous technological application.

Prerequisite: Placement out of foundations MAT and ENG courses.

Michael Dorneman & Carlo Alfare
Course Coordinators and Professor of Chemistry

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**Philosophy of the Course:**

Science concepts courses are intended to provide a broad and useful introduction to various science areas for students not majoring in science or technology. The course is designed to teach the student about nature and the physical universe as it is presently understood by modern, mainstream scientists.

Physical Science Concepts is designed to stimulate your interest and improve your understanding of a variety of related subject areas in the broad realm of Physics and Chemistry. Factual material will be presented with considerable discussion of the technological developments, political concerns, and sociological consequences of the topics considered. A historical perspective will be important to our understanding. It is hoped that your curiosity concerning scientific endeavors and your concern for their consequences will be enhanced. Ten years hence, when you have forgotten many of the specific facts, you may retain a new outlook on the world.

**Quizzes and Examinations:**

Laboratory quizzes will be given at the beginning of the laboratory class. If you are late you will get a zero as there are no make-ups. Each quiz will consist of five multiple choice questions based upon the labs completed in the previous week. If the laboratory was missed, or not made up, it is suggested that as much of the laboratory be completed as is possible (at home and with the help of your laboratory partner) before the quiz is taken. Your lab instructor can also be consulted for help.

Two hourly examinations will be given during the semester. Specific dates and locations for these examinations will be announced at least one week in advance. It is your responsibility to be present at all the examinations and the final examination. The course final examination will be comprehensive and will occur in the 16th week of the semester. An unexcused absence will constitute a zero score on any exam or quiz. This will automatically occur if the course coordinator is not contacted within 48 hours of a missed exam, or beforehand if that is possible (eg. illness).

If you read the objectives and Study Questions, you should be able to determine most of the questions that will appear on exams.

You must have your ID card and schedule to take an exam or test.

**Laboratory Manual and Reports:**

The Laboratory Manual, along with your data, results, graphs, diagrams, and answers to questions will constitute a useful text and guideline for the course, quizzes and examinations. The laboratory reports will be collected weekly and graded (5 points each). They are due immediately at the end of the laboratory in which they are performed. None will be accepted later. They will be graded and returned in the following class so that you have them to study for the quiz. A student who arrives late may not be allowed to participate in the laboratory.
**Mercer's Academic Integrity Policy:**

Academic integrity is violated when a student:

A. Uses or obtains unauthorized assistance in any academic work.
B. Gives fraudulent assistance to another student.
C. Knowingly represents the work of others as his/her own, or represents previously completed academic work as current.
D. Fabricates data in support of an academic assignment
E. Inappropriately or unethically uses technological means to gain academic advantage

Violators will be penalized in accordance with college policy.

READ the MCCC booklet on Academic Integrity

**Guidelines for Courtesy and Respect:**

I would like to welcome all students into an environment that creates a sense of community, pride, courtesy and respect. In order to do this, please make every attempt to come to all classes, to come on time, and to stay until the end of the meeting. There may be a time when you are unavoidably late for class. In that case, please come into the room quietly and choose a seat closest to the entrance. Please turn off all cell phones, and electronic devices and put them in a book bag prior to coming into class. Once a class session has begun, please do not leave the room and then re-enter unless it is an emergency. If you miss a class meeting for any reason, you are responsible for all material covered, for announcements made in your absence, and for acquiring any materials that may have been distributed in class.

It is important that we are all able to stay focused on the class lecture/discussion. For this reason, only one person at a time in the class should be speaking. Side conversations are distracting for surrounding students and for me. As you can see, simple norms of courtesy should be sufficient to have our class run in the best interests of all of us. Thank you in advance for your cooperation.

**Study Questions:**

You should complete the Study Questions at the end of each unit after that unit is completed in lecture. These will be reviewed in the laboratory period as indicated in the schedule. Bring them to the laboratory in which they will be reviewed and receive 2 points for each set you have completed.

**Additional Materials:**

The videos shown in lecture support the lecture concepts. You should be reading in On Giants’ Shoulders: Great Scientists and Their Discoveries by Melvyn Bragg all semester long as indicated in the Topical Outline. Some questions on the examinations will be taken from this book and the videos, including items not mentioned in lecture. There are also available many study aids on my website and in the bookstore.

Help is available in the Science Learning Center (MS 211). Free tutors are also available in the Tutoring Center (second floor Library).
**Grading Procedure:**

Grading will be based on the point system as indicated below:

<table>
<thead>
<tr>
<th>Activity</th>
<th>% of Total</th>
<th>Basis for Points</th>
<th>Max. Pts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Hour Test</td>
<td>22%</td>
<td>Percent</td>
<td>100</td>
</tr>
<tr>
<td>Second Hour Test</td>
<td>22%</td>
<td>Percent</td>
<td>100</td>
</tr>
<tr>
<td>Laboratory Reports</td>
<td>14%</td>
<td>5 points each (13)</td>
<td>65</td>
</tr>
<tr>
<td>Laboratory Quizzes</td>
<td>13%</td>
<td>5 points each (12)</td>
<td>60</td>
</tr>
<tr>
<td>Study Questions</td>
<td>7%</td>
<td>3 points each (10)</td>
<td>30</td>
</tr>
<tr>
<td>Final Examination</td>
<td>22%</td>
<td>Percent</td>
<td>100</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
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<td><strong>455</strong></td>
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</tbody>
</table>

**Bonus Points (maximum) will be available as follows:**

- Term Paper (C Grade, B Grade, A Grade) 4, 7, 10
- Homework Bonus Correct and on Time 9
- Lab Report Forms Bonus sections 44

**TOTAL Bonus Points Available** 63

Other Bonus Points may become available at the discretion of the instructor.

**Grades will be assigned based on the following scheme:** *

- A: Above 425 points (above 93%)
- A-: 405 – 424 points (89% - 93%)
- B+: 390 – 404 points (86% - 88%)
- B: 375 - 389 points (82% - 85%)
- B-: 360 – 374 points (79% - 81%)
- C+: 340 - 359 points (75% - 78%)
- C: 305 – 339 points (67% - 75%)
- D: 250 – 304 points (55% - 66%)
- F: Below 250 points (below 55%)

*Acceptable laboratory performance along with a passed grade on the final examination is required to pass the course. See the Course Objectives for more details. See the last page of the Course Manual for the Grade Record-Keeping Chart.*
<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture Topics</th>
<th>Course Manual</th>
<th>Readings Melvyn Bragg</th>
<th>Laboratory Activities</th>
<th>Videos</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I     Measurements in the Physical Sciences</td>
<td>Exp. 1: Parts A and B</td>
<td>Archimedes</td>
<td>Exp. 1: Measurement Standards &amp; Measurement Systems</td>
<td>“Powers of Ten” “The Metric Film”</td>
</tr>
<tr>
<td>3</td>
<td>IV    Astronomy</td>
<td>Exp. 3: Investigating Gravity Near Earth’s Surface</td>
<td>Newton</td>
<td>Review: Study Question 2 Exp. 4: Magnetism, Motors, Public Service and Pollution</td>
<td>“Electromagnetic Waves”</td>
</tr>
<tr>
<td>4</td>
<td>V     Electromagnetic Interactions</td>
<td>Exp. 4: Magnetism, Motors, Public Service and Pollution</td>
<td>Faraday</td>
<td>Review: Study Questions 3 &amp; 4 Exp. 5: The Reflection of Light</td>
<td>“Relativistic Time Dilation”</td>
</tr>
<tr>
<td>5</td>
<td>VI    Electromagnetic Interactions</td>
<td>Exp. 5: The Reflection of Light</td>
<td>Einstein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>VII   Atomic Structure</td>
<td>Exp. 6: The Refraction of Light</td>
<td>Einstein</td>
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<tr>
<td>7</td>
<td></td>
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<td>Exp. 7: Refraction Lenses &amp; Optical Instruments</td>
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<td>8</td>
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<td>Exp. 8: Waves, Sound, and</td>
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<td>9</td>
<td></td>
<td></td>
<td></td>
<td>“Antimatter”</td>
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</tr>
<tr>
<td>Videos</td>
<td>Laboratory Activities</td>
<td>Readings</td>
<td>Lecture Topics Course Manual</td>
<td>Week</td>
<td>Hour Test II: Units V - VII</td>
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<tr>
<td>&quot;Atoms and Molecules&quot;</td>
<td>Review: Study Question 7 Exp. 11: Measuring an Atom’s Mass</td>
<td>Crick &amp; Watson</td>
<td>VIII: Bonding and Molecules</td>
<td>12</td>
<td></td>
</tr>
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| | | | Lecture Room | | | | | | |
**BASIC REQUIREMENTS:**

Participation in laboratory courses is permitted provided the student has completed the required prerequisites, is a minimum of 16 years of age, or by permission of the instructor and the Dean of the division.

It is the college policy that a student taking the class as an Audit must declare this at the time of registration, and may not attend the laboratory, may not take exams, and may not have quizzes graded.

If you need an accommodation, you must bring the form at least 2 weeks before it will be used.

**GENERAL PERFORMANCE OBJECTIVES:**

1. You must satisfactorily complete the assigned laboratory experiments. Missing 3 or more will constitute an F for the course.

2. You must attend all lectures. If a class meeting is missed for any reason, the student is responsible for content, announcements and acquiring missed materials. Three or more missed lectures may result in a lower grade.

3. You must complete the Hour Tests, the weekly laboratory quizzes, and the final examination.

4. You must achieve a passing grade on a comprehensive final examination.

5. You must demonstrate proficiency in the subject matter by mastering a large part of the material covered by lectures, homework, videos, laboratory work and the texts as detailed in the specific course objectives that follow.

**COURSE COMPETENCIES/GOALS:**

**Course Competencies/Goals:**

The student will be able to:

1. Develop the ability to think critically and reason quantitatively

2. Demonstrate a working knowledge of fundamental physical science principles and concepts

3. Connect physical science concepts to the natural world and to formulate perspectives on social issues influenced by science

4. Develop skills in observation, analysis of data, synthesis of information, organization of data, and the application of the scientific method

5. Evaluate scientific evidence and communicate opinions and conclusions in writing
Course Outline

**General Education Knowledge Goals:**

**Goal 1. Communication.** Students will communicate effectively in both speech and writing.

**Goal 2. Mathematics.** Students will use appropriate mathematical and statistical concepts and operations to interpret data and to solve problems.

**Goal 3. Science.** Students will use the scientific method of inquiry, through the acquisition of scientific knowledge.

**Goal 4. Technology.** Students will use computer systems or other appropriate forms of technology to achieve educational and personal goals.

**Goal 9. Ethical Reasoning and Action.** Students will understand ethical issues and situations.

**MCCC Core Skills:**

**Goal A. Written and Oral Communication in English.** Students will communicate effectively in speech and writing, and demonstrate proficiency in reading.

**Goal B. Critical Thinking and Problem-solving.** Students will use critical thinking and problem solving skills in analyzing information.

**Goal C. Ethical Decision-Making.** Students will recognize, analyze and assess ethical issues and situations.

**Goal D. Information Literacy.** Students will recognize when information is needed and have the knowledge and skills to locate, evaluate, and effectively use information for college level work.

**Goal E. Computer Literacy.** Students will use computers to access, analyze or present information, solve problems, and communicate with others.

**Goal F. Collaboration and Cooperation.** Students will develop the interpersonal skills required for effective performance in group situations.

**Goal G. Intra-Cultural and Inter-Cultural Responsibility.** Students will demonstrate an awareness of the responsibilities of intelligent citizenship in a diverse and pluralistic society, and will demonstrate cultural, global, and environmental awareness.
**SPECIFIC COURSE OBJECTIVES:**

I. **Measurements in the Physical Sciences:**

The concepts and the quantities of time, distance, mass, charge, temperature, area, volume, and density will be treated both in the metric system and in the English system. Recall the films "Powers of Ten" and "The Metric System" and the "Measurement Standards and Measurement Systems" Experiment.

You should be able to:

1. Explain which quantities are fundamental and which are derived.

2. Learn the fundamental units of mass, distance, time, temperature, and charge in the metric system.

3. Learn, use, and convert between the metric prefixes of milli, centi, & kilo.

4. Give at least three characteristics of a good measurement standard.

5. Explain the difference among measurement standards, measurement units, and measurement instruments.

6. State the current measurement standards for distance, time and mass and discuss how measurement standards for time and distance evolved.

7. Define and calculate the quantities: area, volume, and density, in terms of the fundamental quantities (distance and mass), being sure to include units.

8. Distinguish between solid (cubic centimeter) and liquid (liter) volume and how they are obtained, and state the metric relationship between them.

9. Estimate (in metric units) the approximate mass and approximate size of common household objects.

10. Perform some simple comparisons between:
   a. Grams or kilograms and pounds or ounces
   b. Inches, feet or yards and meters or centimeters.

11. Determine the density of an object, given its mass and volume, and explain how and why it would float or sink if dropped into water, or another liquid whose density is given. ("Measuring Mass-Volume Relationship" Experiment)

12. Explain why density is independent of sample size.
13. Given the density of two immiscible (do not mix) liquids, explain which would be on top (or bottom) and why.

14. List and explain how the properties of a substance (atomic masses and spacings) affect its density.

15. Explain how a simple balance works.

16. Convert numbers between decimal and scientific notation and vice versa.

17. Do simple arithmetic in scientific notation.

18. Use the unit-factor method to do conversions between quantities.

19. Compare the Metric and English systems with respect to the accuracy and ease of use.

20. Explain the difference between mass and weight.

21. Describe the contribution of the ancient Greeks to science and measurement.

II. **Motion:**

Speed, velocity, and acceleration will be defined and a variety of kinds of motions will be discussed, including:

a. Motion with constant velocity

b. Motion with constant acceleration

c. Simple harmonic motion

d. Projectile motion

e. Circular and elliptical motion

f. Random thermal motion

Newton's laws of motion will be discussed and evaluated, along with a discussion of work and energy.

You should be able to:

1. Quantitatively discuss the motions above (a-f) and give an example of each. Sketch the graphs of the velocity and position vs time and interpret them.
2. Given an example of motion, determine which type it represents, and vice versa.

3. Describe the vertical and horizontal components of projectile motion.

4. Describe the centrifugal and centripetal forces in circular motion.

5. Determine the period and frequency of a pendulum from appropriate data, and relate this to the pendulum's mass, length, and height of swing.

6. Define speed and acceleration in terms of the fundamental quantities (distance and time).

7. Distinguish between the concepts of speed and velocity.

8. Perform simple calculations to find speed, time, or distance, if two of the three quantities are provided.

9. Perform simple calculations to find acceleration, time, or change in speed ($\Delta v$) for constant acceleration.

10. Use the formula: $d = \frac{1}{2} a t^2$ to find the distance resulting from uniformly accelerated motion (falling objects).

11. Illustrate and explain the various types of acceleration, using examples.

12. Describe the motion of falling objects, explaining the changes in the relationship among time, distance, speed and acceleration. ("Investigating Gravity Near the Earth's Surface" Experiment).

13. State Newton's three laws of motion and provide an explanation of each which indicates that you clearly understand its intent. (Include examples in your discussion).

14. Use the equation: $F = ma$ to compare the acceleration of different masses subject to the same force.

15. Define the derived quantity of force and give its units in both the English and Metric Systems.

16. Define the derived quantity of work, and relate it to the concept of energy.
III. **Gravitational Interactions:**

Laboratory and lecture experience will illustrate the behavior of free falling bodies and universal gravitation. Newton's role in helping man to understand the force involved will be investigated, his conclusions discussed, and its consequences investigated. The consequences of universal gravitation will lead into a discussion of astronomy and the interaction of celestial bodies.

You should be able to:

1. Summarize the pre-Newtonian concept of gravity (eg: Galileo, Aristotle).
2. Identify the work done by Galileo, including the description of an accelerated motion, projectile motion, the moons of Jupiter, etc., and his getting the heliocentric theory more widely accepted.
3. Describe Aristotle's five elements.
4. Describe the contributions to science made by Arab, Egyptian and Assyrian cultures.
5. Describe the impact and nature of Newton and his physics on society, and free will; explain the romantic reaction to all of this.
6. Explain the relationship of science to the Industrial Revolution, citing examples.
7. Write from memory Newton's Law of Universal Gravitation and explain the meaning of each term, and its effect on the gravitational force.
8. Combine Newton's Second Law of Motion with the Law of Universal Gravitation, and show that the acceleration of gravity must be the same for all masses.
9. Use Newton's Law to calculate the force between two objects, given their masses and separation in metric units.
10. Describe the magnitude of the gravitational force between two "isolated" objects such as:
   a. Two people
   b. The Earth and moon
   c. The Earth (or moon) and a person (and the effect as they move further away).
11. Describe the differences and relationship between mass, inertia, weight and force.

12. Explain the connection between ocean tides and universal gravitation.

13. Explain the connection between our atmosphere and universal gravitation.

14. Compare gravitational effects on the earth, the moon, and other planets.

15. Qualitatively describe Einstein's improvements upon the Newtonian view of gravity.

IV. **Astronomy**

We will discuss the breath and scope of the large scale universe with its impact and relationship to life on Earth.

You should be able to:

1. Discuss and describe the earliest contributions to astronomy (eg. Stonehenge, Egyptian, Babylonian, Assyrian, Ancient Greek, Hellenistic and Moslem) in terms of their successes and failures.

2. Discuss the relationship of astronomy to time and to astrology, and give arguments against astrology, and ways of identifying other pseudosciences.

3. Know the relative position and names of the planets in our solar system, and briefly describe some of the features of each one (eg. the clouds of Venus, canals of Mars, red spot of Jupiter, rings of Saturn, tininess of Mercury, etc.).

4. Show how astronomy fits into a general historical and intellectual framework, relating to such historical figures as Pythagoras, Plato, Aristotle, the Romans, Archimedes, Ptolemy, Galileo, Copernicus, Brahe, and others.

5. Know the relative motions of the moon, the Earth, the sun, and the other bodies in our solar system, and what law governs these motions.

6. Describe the basic difference between "inner" and "outer" planets in terms of size, structure, and location, and name those in each category.

7. List the four Galilean moons, the largest moon in the solar system, and the largest moon around Jupiter and Saturn.

8. Describe how Pluto differs from the normal pattern of the planets.

10. Know how the motions and positions of the members of the solar system relative to the length of a "day" or "year" on a planet (including the Earth), to the Earth's seasons to lunar phases, to lunar eclipses, to solar eclipses, and to the apparent motion of the objects in the Earth's sky.

11. Cite examples and describe other celestial bodies and areas (beside the sun, moon and planets) within our solar system (eg. comets, asteroids, meteors Kuiper Belt, Oort Cloud) and explain where they are found and/or what they contain.

12. Cite examples and briefly describe astronomical bodies and groupings in the universe (eg. solar systems, stars, the milky way, galaxies, black holes, nebula, novae, pulsars, quasars).

13. Describe and give relationships among: blue giants, red giants, white dwarfs, neutron stars.

14. Define the distance unit "light year" used to describe astronomical distances.

15. Describe the general distribution and motion of the matter within the universe, and its cause.

16. Describe our galaxy and the location of our Solar System in it.

17. Know a few approximate distances: 93 million miles from here to the Sun, 4.3 light years from here to the nearest star Alpha Centauri, 250,000 miles from here to the moon, and 100,000 light years across the Milky Way.

18. State how we know what we know about the Solar System.

V. Electromagnetic Interactions:

From an essentially non-mathematical treatment which depends heavily on laboratory experiences ("Magnetism, Motors, Public Service and Pollution," Experiment) we will investigate the interaction of static charges, moving charges, and magnetic fields. This will lead us to a basic understanding of the functioning of electric motors, generators, and transformers.

You should be able to:
1. Summarize the historical development of electromagnetic theory, including names and approximate dates (e.g. Franklin, Coulomb, Volta, Oersted, and Maxwell).

2. State the relationship of electromagnetism and the Industrial Revolution.

3. State that electrical charge is a fundamental quantity and give its basic unit.

4. Explain that all neutral matter is composed of equal amounts of the two types of charge: positive and negative; and that if some negative charge is removed the matter becomes positively charged.

5. Write from memory Coulomb's Law, which describes the interaction of non-moving (static) charges, and explain the meaning of each letter in the law.

6. Explain the effect of changing the size of the charges or distances involved on the force between them.

7. Describe the use and operation of the device for studying the electrostatic force (electroscope).

8. Contrast the magnitude of electrostatic forces (Coulomb's Law) with gravitational forces (Newton's Law), particularly in the instances of:
   a. Planetary interactions (moon/Earth)
   b. Atomic realms (electron/proton)


10. Define magnetic force and magnetic field.

11. Describe the nature and interaction of magnets and their magnetic fields, and what can effect a magnet's strength and how.

12. Describe the Earth's magnetic field and how we detect it and other magnetic fields.

13. Describe (with diagrams, if necessary) that:
   a. Charges moving in linear paths generate cylindrical magnetic fields.
   b. Charges moving in circular paths (coils, for example) generate axial magnetic fields (within the coil).
c. Magnetic fields exert forces upon charges moving through them.

d. Conducting loops (or coils) moving through a magnetic field results in an induced current.

14. Relate the principles above to the operation of:

   a. Electric motors
   b. AC generators
   c. Transformers

VI. **Electromagnetic Radiation and the Nature of Light:**

From a historical perspective and through a series of six laboratory investigations (Experiments 5-10), a rudimentary treatment of wave phenomena, and the behavior of light and other electromagnetic radiation will be presented.

You should be able to:

1. Trace the historical developments in man's concepts of the nature of visible light, and summarize existing evidence for both the particle and the wave theories of light.

2. Illustrate that you have a clear notion of the meaning of the amplitude, frequency, wavelength, velocity, and period of a wave form, including their symbols. ("Waves, Sound, and Light" Experiment)

3. Demonstrate (and calculate) the relationship among wavelength, frequency, and velocity, and explain the independence of amplitude to these quantities.

4. List and compare in terms of relative frequencies (or wavelengths) and relative energies (penetrating power) at least the following forms of electromagnetic radiation:

   a. X-rays
   b. Ultraviolet Light
   c. Visible Light
   d. Infrared Light
   e. Radio Waves
   f. Cosmic Rays
   g. Gamma Rays
   h. Microwaves and Radar

5. Give an example, use, or source of each of the above kinds of radiation.
6. Relate the concept of the pitch of a sound or the color of light to the frequency (or wavelength) of its wave form.

7. Relate the concept of loudness of sound or brightness of light to the amplitude of its wave form.

8. Explain the difference between longitudinal waves, such as sound, and transverse waves, such as light.

9. Define and contrast amplitude modulation (AM) and frequency modulation (FM), and their place in the electromagnetic spectrum.

10. Explain the greenhouse effect and give its potential effect on climate.

11. Explain the discovery and use of the X-rays as being able to "see" through flesh and describe other applications of X-rays and who discovered them (Roentgen).

12. Define converging and diverging in relation to mirrors and lenses

13. Describe what happens when light waves strike a surface (eg dull white, dull black and reflecting).

14. Explain with words and with diagrams the ways that light can interact with matter, ("The Reflection of Light" and "The Refraction of Light" Experiments) including some of the details and applications of:
   a. Reflection (plane, concave, and convex surfaces)
   b. Refraction (plane, concave, and convex solids)
   c. Diffraction (narrow slits)

15. Apply the refraction principle ("Refraction, Lenses, and Optical Instruments" Experiment) in describing (in terms of lens placement, lens choice, image size, image location, and image quality):
   a. The function of the human eye.
   b. Corrective lenses (eyeglasses) for near-sightedness and farsightedness.
   c. Cameras and camera lenses.
   d. Film projectors and photographic enlargers.
   e. Microscopes.
   f. Telescopes and binoculars.
16. Relate the curvature, focal length, focal point and magnifying ability of a convex and concave lens.

17. Illustrate and describe the possible events that can occur when two waves meet or "interfere".

18. Qualitatively describe the interference patterns one might observe for a variety of light sources, including:
   a. Incandescent
c. Florescent
e. The Sun
   b. Hydrogen
d. Helium
   f. Neon

19. Show that you have a basic feeling for the use of Bragg's Law to account for the above interference patterns. Specifically, you will be responsible for the qualitative description in the laboratory experiment, ("Measuring Visible Light Wavelengths" Experiment).

20. Explain the nature of the interaction of light with matter as it is used in the black and white photographic process. ("A Chemical Reaction Produced by Light" Experiment)

21. Explain the basic steps in the black and white photographic process for producing both a negative and a positive.

22. Explain to which parts of the electromagnetic spectrum photographic emulsions are most and least sensitive, and why.

23. Explain the nature, production, and applications (eg Holograms) of LASER light and what the letters "LASER" represent.

24. State the speed of light and relate it to Einstein's theory of Relativity. Also explain how we perceive or "see" things.

25. Discuss Einstein's theory of relativity in terms of an object's mass, speed, and time scale.

VII. Atomic Structure:

Using evidence related to our experiments with light, and drawing on important historical developments, we will investigate the nature of the atom.

You should be able to:

1. Summarize some ancient theories concerning the internal structure of matter (eg: Earth, Air, Fire, Water theory).
2. State the experimental verification of the "Atomic Theory" by John Dalton in 1804.

3. Describe the Rutherford scattering experiment and relate its contribution to our knowledge of the structure of the atoms.

4. Qualitatively relate how emission spectra ("Wavelengths of Light" Experiment) verify that different electronic energy levels exist in atoms.

5. Describe the Bohr concept of the structure of an atom.

6. Summarize the gross features of the structure of atoms, including:
   a. The nature of the atom and the nucleus (the kinds of particles, their masses and their charges).
   b. The distribution of electrons in allowed orbitals about the nucleus.
   c. What happens when electrons move to higher or lower energy levels, and what causes it.
   d. The connection between the physical and chemical behavior of an atom and the number of electrons in its outermost orbit (valence electrons).
   e. The basis for construction of the Periodic Table.

7. Show by definition, explanation, or examples that you have a fundamental concept of the following terms:
   a. Electron
   b. Proton
   c. Neutron
   d. Nucleus
   e. Atom
   f. Element
   g. Isotope
   h. Ionization
   i. Atomic number
   j. Mass number
   k. Atomic weight
   l. Valence electrons
   m. Symbol of an element
   n. Nuclear notation
   o. Orbital
   p. Valence shell
8. Explain the fundamental unit of atomic weight: atomic mass units (amu), the current standard for the amu, and how they are used to describe the relative masses of atoms ("Measuring an Atom's Mass" Experiment).

9. Explain why the atomic weights, as written in the Periodic Table, are not integers like the mass numbers.

10. Learn the name and symbol for the following important elements:

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Al</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
</tr>
<tr>
<td>Silicon</td>
<td>Si</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>P</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
</tr>
</tbody>
</table>

11. Describe the basic format of the Periodic Table, its origins, and its relationship to the number of valence electrons; and indicate the following:

   a. Families or groups
   b. Periods
   c. Representative elements
   d. Transition elements
   e. Noble gases
   f. Metals
   g. Semimetals
   h. Nonmetals

12. Define ions, illustrate and distinguishing between anions and cations.

13. Name the Russian scientist given principal credit for devising the Periodic Table.

14. Based on its position in the Periodic Table, determine the number of valence electrons and the most likely ion an element will form.

15. Given the mass number and atomic number of an element (or ion) determine the number of electrons, protons, and neutrons it contains and write it in nuclear notation (and vice versa).

16. Briefly describe the modern "Quantum Mechanical" contributions to our picture of the atom, and how they differ from the Bohr picture.

17. Explain the reason for the stability of the Nobel Gasses and why the other elements try to be like them.
VIII. Bonding and Molecules:

We will briefly investigate in laboratory and lecture the nature of the bonding between atoms in the forming of molecules and compounds, and their basic structure.

You should be able to:

1. Explain what is meant by the words molecule, compound, formula, pure substance, and mixture.

2. Describe the basic features and characteristics which distinguish among:
   a. Metallic bonding
   b. Ionic bonding
   c. Covalent bonding

3. Describe how each of the above bonds is formed between atoms.

4. Explain and give examples of pure substances and mixtures.

5. From an element's position in the Periodic Table, determine which of the above type of bonding it will form with itself or another element, describing how the bond would look, what the overall structure would look like for the molecule or compound, and what formula it would have.

6. From a substance's electrical conductivity in the pure state and in water solution, determine the nature of its bonding ("Classification of Materials by Conduction" Experiment).

7. Provide a qualitative description of the kind of bonding and structures involved in each of a series of compounds, such as:
   a. Water or oxygen
   b. Sodium chloride or calcium oxide
   c. Graphite or diamond
   d. Organic compounds such as benzene, methane or sugar
   e. Magnesium, aluminum, iron, etc.

8. Describe an electron transfer (ionic) bond and how it leads to the overall crystal lattice structure of a substance that involves such a bond.
9. Discuss the covalent bond in terms of the number of electrons shared and the number of bonds formed between atoms.

10. Give a positive and negative ion, write the formula for the compound it would form and state the bonding involved.

11. Discuss the concept of the polarization of a bond and its relationship to polar molecules.

12. Discuss the results of polarization on the properties of molecules (particularly for water).

13. Distinguish among the metals, nonmetals, and semimetals and the general properties which classify them thus.

14. Explain what is meant by the term organic chemistry and organic molecules.

15. Explain the characteristics of the carbon atom which makes possible the existence of millions of carbon compounds.

16. Name and/or draw the structure of simple organic compounds such as methane, ethane, ethylene, acetylene, benzene, and ethanol ("Organic Model Building" Experiment).

**IX. Heat, Temperature, and the States of Matter:**

We will discuss heat energy, temperature, and pressure and their relationship to the states of matter. At the end of the treatment you should be able to:

1. List several different kinds of energy and describe each.

2. Distinguish between kinetic and potential energy and describe examples of converting from one to the other.

3. Demonstrate a knowledge of the three temperature scales by stating their units and the relationship between them.

4. State in degrees Celsius (approximately): What is common room temperature; what is body temperature.

5. State what is meant by "absolute zero."

6. Define the term energy and relate it to work.

7. State the definition of calorie and kilocalorie.
8. Define and contrast the terms heat and specific heat.

9. Distinguish between heat and temperature, and relate them to random thermal motion, and to each other.

10. Explain how to determine in which direction heat will flow from one body to another.

11. Explain the difference between the three methods of transmission of heat: conduction, convection, and radiation; and give examples of each.

12. Explain what is meant by pressure, what causes it in gases (on a molecular level), and what units it has.

13. Explain the effects of pressure and temperature on and between the states of matter, particularly the gaseous state. Include effects at the molecular level.

14. Explain the kinds of molecular motion involved in each of the states of matter, and how close the molecules are.

15. Explain what "change of state" means and how heat energy is involved.

16. Show by definition, explanation, or examples that you have a fundamental concept of the following terms:
   a. Evaporating
d. Melting
   b. Condensing
e. Freezing
   c. Boiling
   f. Subliming

17. Briefly discuss the historical development of thermodynamics and its impact of the Industrial Revolution.
X. **Nuclear Structure, Reactions, and Energy:**

We will briefly probe the nature of the nucleus of an atom and the technology of nuclear reactions. Your mastery of this unit will be based upon your ability to:

1. Provide a qualitative description of the nature of the forces between nuclear particles and discuss the role of electromagnetic forces which must be overcome.

2. Discuss the main simple features of the nuclear force.

3. Show by definition, explanation, or examples that you have a fundamental concept of the following terms:
   - a. Nucleons
   - b. Radioactivity
   - c. Alpha particles
   - d. Beta particles
   - e. Gamma rays
   - f. Fusion
   - g. Transmutation
   - h. Geiger Counter
   - i. Ionizing radiation
   - j. Carbon dating
   - k. Spontaneous fission
   - l. Induced fission
   - m. Critical mass
   - n. Chain reaction
   - o. Radioactive fallout
   - p. Radioactive half-life

4. Discuss the relative number of neutrons to protons in the various nuclei and explain the consequences of and reasons for this ration.

5. Qualitatively summarize the causes and consequences of:
   - a. Alpha decay
   - b. Beta decay
   - c. Gamma decay
   - d. Nuclear fission (what atoms are involved?)
   - e. Nuclear fusion (what atoms are involved?)

6. Given an element's atomic number and mass number, write it in nuclear symbolism, or vice versa.
7. Balance nuclear reactions using nuclear symbolism.


9. Discuss the historical development and use of the atomic bomb.

10. Explain the nature, source of energy, and results of the atomic bomb and of the hydrogen bomb.

11. Describe the results of fusion in stars (include our own sun in the discussion).

12. Discuss all sources of energy in terms of safety, pollution and availability (eg: fossil fuels, geothermal, solar, waterfalls, fission, and fusion).

13. List the practical uses of, the adverse effects of, and the future possibilities for:
   a. Fission reactions
   b. Fusion reactions
   c. Radioactive elements

The specific objectives outlined above should guide you in the course. They explain the level of competency that is expected of you, and the scope of our exploration in the physical sciences. It is an optimistic list of our goals which might occasionally be amended to meet an immediate circumstance. Any changes will be clearly communicated to you. Do not hesitate to question any statements or to request more explicit explanation.

**NOTE:**

When you have surveyed the outline and carefully read the introduction and closing remarks above please stop by my office and sign your name on the agreement posted outside the door.