

LINDEN HALL

"Non Scholae Sed Vitae Discimus" (Seneca)

Instructor: Dr. Mary Lanzerotti

Course: Physical Science

Academic Year: 2009-2010

Course Philosophy: The study of the physical laws that govern our universe is a wonderfully exciting endeavor. I hope that you will come to realize this understanding during the coming year. Many of you may believe that science is simply about memorizing facts and equations, and pushing calculator buttons. Although science does express itself through the language of mathematics, it is a language that can be quite elegant (*"The book of nature lies open for all to read, and it is written in the language of mathematics"*, Galileo). However, in order to enjoy science and to master the desired skills, one must come to an understanding of some basic principles. This requires more than blind memorization and calculator manipulation. In other words, while it is essential to arrive at the correct response to a homework problem, it is equally important to understand the physical situation well enough that you can *verbally* explain it to another individual. Using formulas whose origins, meanings, and application limitations are unknown to you will make a deeper understanding impossible.

Physical Science requires an interesting blend of critical thinking and imagination. The reward is that, with hard work, talents are nurtured that will prove invaluable to whatever career you pursue. Throughout the year, I will act as your guide on this exciting journey. You must supply the effort, but please seek my assistance whenever it is needed [1].

In this course, we will learn to describe aspects of nature and its behavior. We will use many specific and new examples to show connections between the past, present, and future in science [2]:

1. We will learn about the fundamental theories and beautiful experiments of distinguished scientists and engineers of the past, present, and future. From the past several centuries, these scientists include Newton, Galileo, Da Vinci, Brunelleschi, and Ben Franklin, among others. At the same time, some of these distinguished individuals were also architects, artists, and/or statesmen. We will also learn about twentieth-century scientists such as Einstein, Bohr, Heisenberg, and Feynman, who developed our present understanding of science. Looking toward science of the future, we will learn about living scientists and engineers who are developing new theories and experiments that are intended to develop and extend our fundamental understanding of nature and complex phenomena.
2. We will learn to appreciate how the scientific theories developed in the way of the ancient scientists are still absolutely useful today; specifically, we will see connections to contemporary science and engineering. For example, Newton's Laws of Motion are still used today by living scientists and engineers if they are not describing quantum phenomena.
3. We will learn how progress in science continues to be achieved and how scientists and engineers disseminate their new material to others. Toward this goal, we will learn how to talk about scientific concepts, how to observe nature, how to record our observations, and how to communicate these observations to others.
4. We will discuss examples presented in the book and then develop general statements to enhance our

understanding of the material.

- Course Requirements:**
- 1) Text: Holt, Physical Science
 - 2) Paper for notes
 - 3) Large 3-ring Binder (Homework)
 - 4) Laboratory Notebook purchased at LH
 - 5) Scientific calculator
 - 6) Observation Notebook purchased at LH
 - 7) Metric graph paper purchased at LH
 - 8) Consistent work

Grading Procedure: Grades are based on a combination of major exams, tests, quizzes, and writing assignments (including lab reports). Tests will be worth twice as much as quizzes and lab reports. As stated in the Student Handbook, “To emphasize the importance of growth through the school year, the weight of each trimester grade has been changed. The first trimester will count as 15%, the second as 25%, the third as 35%, the mid-year exam as 10%, and the final exam as 15%.”

Grading Scale: The LH grading scale will be employed as indicated in the handbook.

A- to A+	90-100	D- to D+	60-69
B- to B+	80-89	F	0-59
C- to C+	70-79		

Homework Policies: Homework is the most critical component of the learning process. The following policies are necessary to remain in good standing in this class.

1. Assignments can span one to several days work and as such due dates may occur approximately daily to once each week to ten days. It is the student's responsibility to check homework due dates.
2. Despite the extended nature of the assignments it is imperative that students perform their homework, whether reading and/or writing, on a daily basis.
3. Effort estimates for assignments are 30 minutes per night. Written assignments must be neat, complete, and timely.
4. All submitted assignments must begin with the student's name, the date, the class title, and the period.
5. When returned, homework (and all submitted items: tests, quizzes, labs etc.) is to be stored in your 3-ring binder.
6. Study groups can be effective. However, when a student submits an assignment, he/she is stating that the material submitted has been fully comprehended. Therefore, joint submissions and plagiarism are unacceptable.

Classroom Policies:

1. Daily *prepared* attendance is mandatory.
2. The student is solely responsible for any material covered or announcements made during her absence.
3. **The school's attendance policy will be strictly enforced.**
4. Inappropriate, disrespectful, or dishonest behavior is unacceptable. Disruptive students will be removed from class and referred to the Dean.
5. Cheating or plagiarism will result in zero credit for the assessment. Such incidents may be referred to the Honor Council.

Observation Notebook: In consultation with the instructor, each student will choose something in nature to describe daily and measure in an Observation Notebook. For example, the topic may be the daily temperature (taken at the same time each day), the quantity of rainfall, or some other observable. Students will write a short description of their observations and will quantify these daily observations with a measurement. During the third trimester, students will compile their observations into a Student Report and Poster.

Additional Help: Feel free to meet me for extra help or to arrange an appointment. I am available all five school days during the Academic Help period and at meals.

Your Name: Your name will appear on all work submitted to me. Therefore, as a matter of personal pride, I expect all such submissions to be of the highest quality. No one else bears your name; honor it well.

Finally, relax !! If you work hard, you will be fine. Students who prepare diligently for class each day generally do well.

I welcome you to my classroom. Please do not hesitate to ask questions---regardless of how simple you may perceive them to be! I am here to help. I ask that you take pride in all that you do. Commence working at once, and we can begin to learn together!

References.

This syllabus was expanded from a previous syllabus provided by Dr. Stumpo with additional extensive discussions with Prof. Lacarbonara.

[1] Dr. Vincent Stumpo, Linden Hall

[2] Prof. Walter Lacarbonara, University of Roma La Sapienza

Tentative Physical Science Schedule

Text: *Physical Science* (Holt, Rinehart and Winston, 2008)

<u>Week</u>	<u>Chapters</u>	<u>Sections</u>	<u>Topics</u>
1	1	All	Scientific Notation
2	1	All	SN & Arithmetic
3	1	All	SN & Arithmetic
4	1	All	Units & Conversions
5	1	All	Units & Conversions
6	1	All	Scientific Measure.
7	1	All	Lab Report Format
8	1	All	Graphing Techniques
9	1	All	Graphing Techniques
10			Pasco Computer
11	11,12	All	Kinematics

1	11,12	All	Kinematics
2	11,12	All	Kinematics
3	11,12	All	Dynamics
4	11,12	All	Dynamics
5	11,12	All	Friction
6	12	All	Gravity
7	12	All	Gravity
8	11	All	Momentum
9	13,14	All	Review/Mid-Year Exam
10	13,14	All	Energy
11	3	All	Energy & Matter
12	3	All	Chemical Reactions

1			Lab Technique
2			Lab Technique
3			Lab Technique
4	4	All	Basic Atomic Theory
5	4	All	QM Atomic Model
6	4	All	QM Atomic Model
7	4	All	QM Atomic Model
8	5	All	Chem. Periodicity
9	5	All	Chem. Periodicity
10			Comp. Review
11			Review & Exam

Quantitative Physical Science

I. Basic Mathematical Techniques of Science

A. Scientific Notation and its Arithmetic: Students must be able to perform basic arithmetic involving numbers expressed in scientific notation with and without the use of a calculator. With noted exceptions, the use of calculators should be greatly limited throughout this course. Extensive drilling is anticipated.

1. Writing Numbers in Scientific Notation (SN). Standard Format.
2. Arithmetic of Numbers in SN: Addition, Subtraction, Multiplication, Division, Raising to a Power (integer and fractional), Taking a Root.
3. Students will be extensively drilled so that they can quickly arrive at good estimates for arithmetic procedures without the use of a calculator.

Example: $(6.87 \times 10^{-5})^2 (1.12 \times 10^3) / (2.58 \times 10^{-2})$

Students must be skilled enough to arrive at the estimate of 2×10^{-4} within 30 seconds.

4. Review the concept of a percent as a part over a whole. Use SN.
5. The algebra of solving for a single unknown. Examples will be drawn from equations that will be used throughout the course, e.g.,
 $\Delta x = v_0 t + \frac{1}{2} a t^2$. The quadratic formula will not be covered.

B. Units of Measurement (SI): Defined (8) and Derived.

1. Metric Prefixes
2. Defined Units (8): Meter, Kilogram, Second, Kelvin, Degree, Mole, Ampere, Candela.
3. Conversion between units via factor-label method. (Extensive drilling)
4. Addition and Multiplication with units
5. Derived units to include: Density, Velocity, Acceleration, Force, Energy, Pressure, Specific Heat, Area, Volume. Extensive practice on converting area and volume units.

C. Sensitivity, Uncertainty, Accuracy and Precision in Scientific Measurement

1. All measurements must be recorded to the proper number of significant digits. With all measuring devices, every digit known with certainty is recorded **plus** one estimation position. Practice must be provided with balances, burets, graduated cylinders, rulers, vernier calipers, thermometers, barometers, etc.
2. Rules for arithmetic involving the significant digits of measured quantities. The rule for addition/subtraction (last common column) is different than the rule for multiplication/division (least number of significant digits).
3. Basic Definitions: Accuracy, Precision, Percent Error, Percent Difference. Provide drilling for the last two.

D. The Standard Laboratory Format

1. Data must be **properly** recorded in LH Standard Laboratory Notebook. Data is not to be recorded on loose leaf or classroom notebook. Each student records the data independently.

Example: When massing, 0.25 g NaCl is an unacceptable data entry.

Required Format:	Mass of NaCl and Weighing Boat:	0.757 g
	<u>Mass of Empty Weighing Boat:</u>	<u>0.503 g</u>
	Mass of NaCl	0.254 g

All data entries must be in pen. No white-out or complete cross-outs permitted. Single line through mistaken data. Carbon copy of data is submitted by each student prior to leaving the lab room.

2. PreLab: Computer-generated and presented on the lab day. Theory section is vital.
3. Complete Lab Report: Data must be in Tables, Charts, etc. Sample Calculations must be present. Error Analysis section is vital; includes Sources of Error and Percent Error. Correctable mistakes are not considered acceptable errors.

E. Graphing Techniques:

1. Students must learn to generate graphs by hand before employing calculators or computers. Graph paper required.
2. Distinguish between independent and dependent variables.
3. Selection of appropriate scales for the axes.
4. Direct (linear) vs. Indirect (hyperbolic) Proportions. The role of the proportionality constant (and its units) in a direct proportion.
5. The equation of a straight line: $V = aT + b$ (students will know this as $y = mx + b$) where V is the dependent variable, T is the

independent
Students will
computing slopes,
given independent
unit !!

variable, a is the slope and b is the vertical intercept.
become skilled in plotting and analyzing data by
intercepts and values of the dependent variable from
variable values. Remember each quantity has a

6. Experiments to demonstrate direct proportions (Mass vs. Volume yielding Density) and indirect proportions (Boyle's Law: Pressure vs. Volume of an Ideal Gas using pressure probes see C-07 in Pasco)

F. Computer Technology in Science

1. Familiarity with Pasco's Science Workshop: Hardware and Software
2. Familiarity with Scientific Probes: Initially Temperature & Pressure
3. Familiarity with Data and Graphical Analysis using Science Workshop
4. Experiments to employ temperature probe (Specific Heat of a metal) and pressure probe (Boyle's Law).

II. The Analysis of Motion

Once familiar with the Pasco Science Workshop, some of the Intro. Physics Labs can be conducted. See the Pasco Physics Manual Volume 1.

A. Kinematics

1. Vectors vs. Scalars
 2. Kinematic Descriptors: Displacement, Velocity, and Acceleration
 3. Average Quantities and Instantaneous Quantities
 4. Equations for Constantly Accelerated Motion and their Applications
- Students must understand the derivations of the following four equations.

$$v_f = v_o + at$$

$$1/2(v_o + v_f) = \Delta x / t$$

$$\Delta x = v_o t + 1/2 at^2$$

$$v_f^2 = v_o^2 + 2a\Delta x$$

**These equations are only valid
for systems at constant acceleration.**

4. Free Fall: The Constant Value of the Earth's Gravitational Acceleration
5. Graphical Analysis of Motion: Numerous Examples including displacement vs. time, velocity vs. time, and acceleration vs. time.

Understanding of the slopes and intercepts of any linear

relationships.

6. **Numerous Mathematical Sample Problems.**

B. Dynamics: The Laws of Newton

1. Inertia: The Law of Galileo in contrast to Aristotle. A force is only needed to **change** (Galileo) a state of motion, not to **maintain** (Aristotle) it. An object with zero net force on it may still be in motion; constant velocity motion.
2. Force and Acceleration: ($F = ma$) Example: An object's weight is proportional to its mass ($F_w = mg$)
3. Newtonian Couples: Forces are two-bodied interactions that come in equal and opposite pairs with each force acting on a **different** object.
4. These three laws are subtle and can be easily misunderstood. Care and drilling are required.

C. Friction and Normal Forces

1. Friction forces result from surface contacts to oppose the direction of motion or the tendency for motion.
2. The magnitude of the friction force is proportion to the normal (perpendicular) force that results from surface contact. The proportionality constant is dimensionless and referred to as the coefficient of friction.

$$F_f = \mu F_n$$

3. The difference between the friction force and the coefficient of friction will be emphasized.
4. Sample Problems

D. Gravitation

1. Newton's Universal Gravitation: Two massed objects attract each other with a force proportional to each of their masses and inversely proportional to the square of the distance between them. **Samp. Problems.**
2. The Inverse-Square Law. Students will be able to respond quickly to questions such as: Two bodies experience a 40 N gravitational force. If the mass of one of the objects and the distance of separation are both reduced by a factor of two, determine the new gravitational force. (80N)
3. The Constant Acceleration of Earth's Surface Gravity (g). Two objects of different mass will experience different gravitational forces with earth, but will experience identical gravitational accelerations. This critical distinction will be explained conceptually, and proven mathematically.
4. Orbiting Objects as Falling: The "weightlessness" astronauts experience while in orbit is not because they are beyond the Earth's gravity. On the contrary, the Earth's gravity causes the astronauts and their ship to fall like any other object, but since they are moving so quickly perpendicularly to the force, they actually fall around the planet.

E. Momentum

1. Classical Definitions ($p = mv$) A Vector. Sample problems.
2. Momentum is conserved in a **given direction** only when the net force **in that direction** is zero. Momentum is conserved during collisions.

F. Energy

1. Definitions: Work, Kinetic Energy, Potential Energy (gravitational), Mechanical Energy, Thermal Energy, and Power
2. Introduce basic equations for kinetic energy ($K = 1/2mv^2$) and gravitational potential energy ($U_g = mgh$). Sample Problems.
3. Conservation of Mechanical Energy: Mechanical Energy is conserved when all energy remains as kinetic or potential, for example when heat is not created. Sample Problems using Energy Conservation. Examples: Landing speed of a falling object or the maximum altitude of an object thrown upward with a given speed.

III. Matter, Chemical Reactions, and Laboratory Technique

A. Basic Descriptions of Matter

1. States of Matter: Solids, Liquids, Gases (Define Ideal Gas Behavior)
2. Basic Definitions: Atom, Molecule, Element, Compound, Solution, Mixture, Colloid, Suspension, Homogeneous, Heterogeneous, Physical & Chemical Changes

B. Chemical Reactions

1. Understanding of the behavior of reactants in the following reaction types: acid-base, precipitation, combustion, generation of a gas, redox. The ability to correctly predict products is expected.
2. Balancing Reactions
3. The Mole: Students should be able to convert between particles, moles and grams.

C. Basic Laboratory Techniques and Measurements

The lab program should have already developed some of these skills. The remainder should be addressed at this time.

1. Skills will be developed in the following areas:
 - a. Proper use of a Bunsen burner and striker
 - b. Proper technique for massing, including zeroing a balance and the need not to zero a balance when massing by difference
 - c. Proper pipetting technique using bulbs, pumps & micropipettes
 - d. Proper buretting technique, including proper hand positioning
 - e. Calibration and use of the pH probes (Pasco)
 - f. Reading a volume in a graduated cylinder (reading the meniscus)
 - g. Estimating the uncertain digit in measurements (length, temperature, et cetera)
 - h. Angle measurement with a protractor
2. Preparing volumetric solutions from solid solutes using molarity and percent by mass concentration scales. Emphasis on cleanliness.
3. Preparing a dilution sequence from an aqueous stock solution

IV. Atomic Theory: The Structure of Matter

A. Basic Atomic Theory

1. Becquerel: Radioactivity: alpha, beta, and gamma radiation
2. Thomson: Cathode Ray Tubes and The Raisin Cake Model of the Atom
3. Rutherford: The Gold Foil Exp. and The Planetary Atomic Model
4. Bohr: Postulates of Atomic Structure
 - a. Electrons are confined to certain quantized orbits
 - b. Electrons emit or absorb energy when they **change** orbits: Line Spectra & Flame Tests
5. Nucleon Properties
 - a. Atomic and Mass Numbers (as distinct from Atomic Mass)
 - b. AMU Scale, Atomic Mass, Weighted Averages, and the Mole
 - c. Conversion between grams, moles, and particles

B. The Quantum-Mechanical Model of the Atom

1. Limitations to the Bohr Model
 - a. No theory to explain energy quantization
 - b. Model failed to predict line spectra of multielectron atoms
2. Wave Mechanics
 - a. Line Spectra - experimentally demonstrated quantization
 - b. de Broglie's Matter Waves (qualitative) Conclusion: Electrons have wave properties that cannot be ignored.
 - c. Heisenberg's Uncertainty Principle: The act of measurement disturbs that which you are trying to measure. It is impossible to know precisely both the position and velocity of an object simultaneously. This eliminates the notion of an electron moving in a circular orbit for we would know both (x and v) exactly.
 - d. Wave Mechanics is developed to replace Newtonian Mechanics that fails to work for subatomic systems that are small enough to have appreciable wave natures.

3. Wave-Mechanical Model of the Atom: **The orbital replaces the orbit.**

The notion of the electron as a little ball whose position and trajectory can be accurately known and predicted is replaced in Quantum Mechanics by the concept of the electron as a probability cloud. It is now a fuzzy electron with somewhat uncertain position. What we can know about an electron is provided by the values of the 4 quantum numbers.

know about an numbers.

- a. The possible energy values for electrons are quantized with unequal spacings
- b. High Probability Districts: Orbitals or Clouds (due to HUP)
- c. Quantum Numbers: n, ℓ, m_ℓ, m_s . This set of four quantum numbers provides us with the knowable information concerning an electron. Specifically,

(n-1)

- | | |
|-------------------------------------|--------------------------------------|
| 1. n --- energy state | $n = 1, 2, 3, \dots$ |
| 2. ℓ --- orbital shape | $\ell = 0, 1, 2, \dots$ |
| 3. m_ℓ --- orbital orientation | $m_\ell = -\ell \dots 0 \dots +\ell$ |
| 4. m_s --- electron spin | $m_s = -1/2 \text{ or } +1/2$ |

From these relationships, we can generate all possible orbitals. For example, in the second energy level ℓ can equal 0 or 1.

When the value is 0 we have an s type orbital. When the value is 1 we have a p type orbital. In addition, when ℓ equals 0, then m_ℓ can only equal 0. Therefore there is only one s type orbital in the second energy level. When ℓ equals 1, then m_ℓ can only equal -1, 0, or +1. Consequently, there can be three different p type orbitals in the second energy level ($p_x, p_y,$ and p_z).

Since ℓ cannot equal 2 do not exist. Since each orbital can accommodate two electrons (one with each spin state), then the second energy level can "hold" 8 electrons. This is the basis for the "Octet Rule" (2 e- in the s orbital and a total of 6 in the p).

in the second energy level, 2d orbitals orbital can accommodate two then the second energy level basis for the "Octet Rule" (2 the p).

- 4. Electronic Configurations and Line Diagrams (Arrow Notation)
 - a. Pauli's Exclusion Principle: Unique Quantum Descriptions: No two electrons within the same atom can have identical sets of quantum numbers.
 - b. Hund's Rule: Electron Pairing: In degenerate (equal energy) orbitals, electrons will not pair up until all orbitals are half-filled. Carbon is $2p_x^1 2p_y^1$ not $2p_x^2$ in the ground state.

of the 4

C. Chemical Periodicity

1. The Periodic Table: The table of the elements was arranged the way according to experimental evidence about similarities in chemical reactivities of the elements. It is essential to demonstrate that the quantum mechanical model of the atom explains these observed patterns in reactivity.

- a. Origins and Motivation: Mendeleev
- b. Explanation via Quantum Mechanical model of the atom
- c. Dissection of the Periodic Table
 1. Families or Groups and Periods
 2. Metals, Nonmetals, and Metalloids
 3. Main Group (s or p), Transition (d), Inner Transition (f)

2. Periodic Properties: Ionic Charge, Oxidation Number, Ionization Energy, Electronegativity, Atomic & Ionic Radii, Ionic/Covalent Tendencies, Electron Affinity