

Applied Science Research (ASR)

Course Goals and/or Major Student Outcomes:

- Acquire a true understanding of modern physics and engineering topics not normally included in high school or college first year courses
- Demonstrate ability to design and conduct Laboratory experiments
- Develop analytical thinking skills through reading published science articles, problem solving, designing experiments, and analyzing data
- Demonstrate an understanding of basic statistics, including error analysis, needed to analyze data in a professional manner
- Develop their ability to write critically and clearly
- Demonstrate ability to write and give a professional science presentation
- Acquire skills necessary to work with equipment requiring modern technological skills

Course Outline

First Semester: First 4 topics done every year. Four other topics from below are chosen based on interests of students. Topics not done in first semester can be done as intensive research projects for 2nd semester.

- I. Analysis of how a car engine works
 - a. Chemical Structure of gas and how it burns
 - b. Thermodynamics
 - c. Pressure and Volume curves
 - d. Heat Engine
 - e. Carnot cycle
 - f. Electric Engine
 - g. Hydrogen fuel cells
 - h. Lab: Build a Sterling Heat Engine calculating efficiency
 - i. Lab: Build an electric motor calculating efficiency

- II. Data Analysis
 - a. Graphing
 - b. Probability
 - c. Basic statistics
 - d. Regression analysis
 - e. Error bars
 - f. Chi squared fit

- III. Radiation and Carbon dating
 - a. Periodic table
 - b. Isotopes
 - c. Types of radiation
 - d. Half-life

- e. Carbon dating
- f. Intro to Quantum Mechanics
- g. Lab: Determining half-life of an unknown
- h. Lab: Energy spectrum and spectral lines
- i. Lab: Carbon date something at Lawrence Livermore

IV. Atmospheric Science

- a. Composition of Atmosphere
- b. Pressure vs. altitude
- c. Temperature vs. altitude
- d. Error Analysis
- e. $PV=nRT$
- f. Global warming
- g. Lab: Contour map of neighborhood
- h. Lab: Weather balloon launch with pressure and temperature probes, data compared to exponential and NASA models
- i. Lab: Absorption levels for various gases
- j. Lab: Determining the amount of CO and CO₂ using absorption detector
- k. Lab: Trip to NASA station in Colorado to use high quality equipment

V. Process of Photosynthesis

- a. Chlorophyll and other pigments
- b. Chemistry of photosynthesis
- c. Light-dependent reactions
- d. Light-independent reactions
- e. Error Analysis
 - i. Statistical
 - ii. Systematic
- f. Lab: Reaction rates of photosynthesis as a function of light intensity
- g. Lab: Reaction rates of photosynthesis as a function of light wavelength
- h. Lab: Correlation of intensity and wavelength of light in photosynthesis

VI. Quantum Mechanics

- a. Atomic spectrum
- b. Basic principles of quantum mechanics
 - i. Wave-particle duality
 - ii. Uncertainty principle
 - iii. De Broglie wavelength
 - iv. Pauli exclusion principle
- c. Schrodinger equation
- d. Particle in a box
- e. Hydrogen atom
- f. Lab: Double slit experiment
- g. Lab: Photoelectric effect
- h. Lab: Atomic Spectra

- VII. Nuclear magnetic resonance
 - a. Resonance
 - b. Electron and proton spin
 - c. How MRI machines work
 - d. LCR resonant circuit
 - e. Lab: building a pick-up coil for magnetic fields
 - f. Lab: Trip to SRI lab with resonant Coil detectors and Hall chip detectors
 - g. Lab: electron spin

- VIII. Particle Physics
 - a. Conservation Laws
 - b. Standard Model
 - c. Feynman Diagrams
 - d. Lab: plot momentum distribution from various radioactive sources using cloud chamber and variable magnets
 - e. Lab: using CERN and SLAC data to confirm conservation laws

- IX. Relativity
 - a. Galilean Transformation
 - b. Lorentz Transformation
 - c. Speed of light derivation
 - d. Special relativity
 - e. Intro to General relativity
 - f. Lab: speed of light in fiber optics
 - g. Lab: speed of light

- X. Green Energy –solar, wind, hydro, rooftop water heaters in china
 - a. Over view
 - b. Principle of each
 - c. Build a working model of each
 - i. Solar energy
 - 1. Energy vs frequency of light
 - 2. Luminosity
 - 3. Semi-conductors
 - 4. Diodes
 - 5. inverter
 - ii. Wind mill with EM generator
 - 1. Vectors
 - 2. Generators
 - 3. capacitors
 - iii. Hydro –build mini river system with EM generator
 - 1. Pelton wheel and impulse, conservation of momentum
 - 2. Generators
 - 3. capacitors
 - iv. Roof top water heaters
 - 1. Heat capacitance

2. Luminosity

- d. Energy saver light bulbs
 - i. Use light sensor to map out intensity of energy saver light bulb and compare to map of regular bulb
 - ii. Use light sensor to map out frequency spectrum and compare both
 - iii. Compute efficiency of both using, light map and IV info
- e. When to turn out lights
 - i. Use current transducer and voltage probe to computer (like vernier) to map current surge and calculate when (i.e. how much time) its advantageous to turn out lights
- f. Solar water heater contest

XI. Astronomy

- a. Solar System
- b. Formation of the Universe
- c. Life cycle of a star
- d. Current ideas on the universe and its fate
- e. Lab: Phases of moon and seasons
- f. Lab: Earth's radius using shadows
- g. Lab: Height of mountains and crater walls on Moon
- h. Lab: Measure rotation speed of Earth and Moon using digital camera and pixel analyzer program

2nd Semester Intensive Research Projects

Students choose a research project to specialize here or at a university or company with a mentor. All research projects require the following. In addition to your own ideas, some other choices are the topics not covered in first semester and the ones below.

- *Research and understanding of the theory (including calculations) –for building projects this can be a mechanical drawing, spec. sheet and description of how it works)*
- *Research experiment or building of a project*
- *Weekly presentations and discussion*
- *Final presentation*
- *Final research paper*

I. Magnetically Levitated Train

- a. Brief history of trains concentrating on the mechanics
- b. Physics of how it works
- c. Build a model maglev
- d. Current prospectus of trains

II. Cosmic rays and Muon lifetime

- a. Standard Model structure
- b. Feynman diagrams
- c. Cosmic ray origins
- d. Experiment: cosmic ray flux vs. altitude
- e. Experiment: cosmic ray flux from solar flares
- f. Experiment: muon lifetime

III. Doppler Effect

- a. Sound
 - i. Do experiments using sound probe and fast fourier transform
 1. bicycle wheel
 2. Ambulance or fire engine
- b. Light
 - i. Red shift
 - ii. Theories of the universe
 - iii. Dark matter
 - iv. Dark Energy

IV. Physics of Baseball

- a. Fluid dynamics
- b. Air resistance
- c. Experiment: wind tunnel and curve ball analysis
- d. Experiment: impulse force and bat speed

- V. Physics of Skiing
 - a. Vector forces
 - b. Latest theories on friction on ice
 - c. Friction at various speeds
 - d. Experiment: 3-axis accelerometer data
 - e. Experiment: mapping the ski slope using accelerometer readings

- VI. Astronomy
 - a. Current theories on formation of Universe
 - b. Variable stars
 - c. Solar flairs
 - d. Comet tracking

- XII. The Hall Effect
 - a. Electro-magnetism and Lorentz force
 - b. The Hall effect
 - c. Lab: using hall chips to measure magnetic fields
 - d. Lab: using hall chips to measure current non-intrusively
 - e. Lab: magnetic field mapping

- VII. SA Amateur scientist experiments

- VIII. Breaking Glass with Sound Engineering Project
 - a. Sound waves
 - b. Resonance
 - c. Bessel functions
 - d. Build: Glass breaker with low decibel sound waves

- IX. Shaker table and bridges
 - a. Structural design of bridges
 - b. Model bridges and force calculations
 - c. Earthquake physics
 - d. Build: shaker table and bridges showing resonance

- X. Tesla coil
 - a. Resonant circuits
 - b. Magnetism and flux
 - c. Physics of lightning
 - d. Build a Tesla coil

- XI. Batteries
 - a. History
 - b. Principles of operation
 - c. Rechargeable
 - d. Build a battery