

## Astronomy and Physics Research Course Outline

Astronomy and Physics Research is an extension of the curriculum in Chemistry, Physics and Astronomy and Space Science emphasizing the application of experimental design to selected advanced topics in these subjects.

From the AUSD course proposal:

1. Students will learn how experiments are designed.
2. Students will design their own experiments and analyze the experiments of others.
3. Students will learn how astronomers and other scientists gather and reduce data.
4. Students will collect, reduce, and report astronomical observations.
5. Students will write testable hypotheses suitable for a high school science course or science fair.
6. Students will learn advanced instrument techniques, record-keeping, file management, data reduction, graphing techniques, and how to construct a scientific research paper.
7. Students will conduct a scientific research project and present the results in a public setting, and publish the results in a setting beyond the classroom.
8. Students will learn how to find best-fit curves, estimate error of measurements, how to reduce the error in measurements, and how to control interfering variables in experimental design.

### Content Outline

- 1) Introduction to Experimental Design
  - a) Measurements in Physical Science and Astronomy
  - b) Random error vs. systematic error
  - c) Accuracy vs. Precision
  - d) Standard deviation and significance
  - e) Detailed analysis of significant figures
  - f) Interpolation and Extrapolation
  - g) Small number statistics
- 2) Background research (Paper Analysis Activity)
  - a) Sources of information (“the literature”)
  - b) Use of internet research /reliability of sources
  - c) Interviewing researchers/seeking a mentor
  - d) Establishing a working hypothesis
  - e) Understanding independent and dependent variables
  - f) Causal relationships vs. correlations
  - g) Writing a hypotheses which can be answered
  - h) Reading and Writing research papers
    - i) Reading papers
      - (1) Analyzing the Structure
      - (2) Identifying the hypothesis
      - (3) Sources of data

- (4) Sources of error
    - (5) Addressing the hypothesis in the conclusion
  - ii) Writing research papers - introduction
    - (1) Audience
    - (2) Peer Review
    - (3) Collaborative papers
    - (4) Seeking a valid hypothesis
- 3) Data collection
  - a) Organizing data
  - b) Multi-variable experiments
  - c) Tracking interfering variables
  - d) Data analysis (Centripetal Force lab)
    - i) Best fit lines
    - ii) Curve fitting/graph straightening
    - iii) Binning and histograms (Radiation lab)
    - iv) Interpolation/Extrapolation
    - v) Correlation coefficients
- 4) Tools and Techniques
  - a) Video analysis of motion
    - i) Basic kinematics (acceleration lab)
    - ii) Conservation of momentum (momentum lab)
    - iii) Analysis of motion within the Crab Nebula (pending)
  - b) Optoelectronic and piezoelectric sensors
    - i) Photogates- (Conservation of Energy and sinusoidal motion lab)
    - ii) Force and acceleration sensors – (rocket impulse analysis lab)
      - (1) Includes numerical integration introduction
  - c) Analysis of optical equipment
    - i) Determination of plate scale (plate scale lab)
    - ii) Determining the figure of a mirror
    - iii) Focal length, aperture, Dawe’s Limit, collimation (telescope design lab)
    - iv) Charge coupled devices (CCDs)
      - (1) Comparison to chemical film
      - (2) Demonstration of reciprocity failure
      - (3) Bloom
      - (4) Review “Introduction to image processing” from astro class
      - (5) Frequency response (‘Q’ vs. wavelength)
      - (6) Small number statistics revisited
      - (7) Construction of color images (“Pretty Pictures” activity)
- 5) Pre-fabricated Exercises in Experimental Procedure
  - a) HOU: Measuring Jupiter’s Moons lab
    - i) Content: Gravity, ratios, Kepler’s laws, curve fitting
  - b) TLRBSE: Spectroscopic Analysis lab
    - i) Content: Atomic structure, quantum mechanics, Doppler effect

- c) Measuring the distance to the moon through parallax lab
  - i) Content: Geometry application, plate scale, coordinate transforms
- d) TLRBSE: Distribution of novae in M31 as a function of radial distance lab
  - i) Purpose: Verification of published experimental results
  - ii) Content: Logarithms, brightness ratios, geometry, data reduction

6) Participation in Pre-Existing Experimental Research Projects

Students will participate in at least three of the following projects, and more as time permits.

- a) HOU: Supernova Search
- b) TLRBSE: Nova search
- c) HOU: Asteroid search
- d) TLRBSE: AGN Spectroscopy
- e) Projects with amateur astronomers
- f) Radio telescope with RA 1420 project
  - i) Current research question: Does the angle between Jupiter, Earth and Io affect the strength of radio emissions from Jupiter?

7) Selection and Pursuit of a Research Project \*

- a) Project Selection
 

The student will:

  - i) Recognize own interests, strengths, and resources, and select a relevant, useful topic that solves a problem.
  - ii) Research topics in library, news articles, and magazines, and with professionals in the field.
  - iii) Evaluate another's research topic.
  - iv) Select a topic which can be completed within the constraints of the resources available.
- b) Research Project Proposal
 

The student will:

  - i) State a purpose.
  - ii) Create an experimental procedure which is duplicatable, measurable, and controllable.
  - iii) Propose a hypothesis.
  - iv) List materials.
  - v) Assess strengths and relate constructive criticism of others.
- c) Library and Internet Research
 

The student will:

  - i) Research, evaluate, organize, and synthesize library and internet information.
  - ii) Identify source, prepare questions, an interview or correspond with a professional in the field.
  - iii) Take notes on chosen topic and speech.
  - iv) Write an extensive research paper on the available literature on their chosen topic.
  - v) Write bibliography of paper.
- d) Experimental Research Paper

The student will:

- i) Synthesize purpose, review of literature, hypothesis materials, procedure, results, and conclusion.
- ii) Write a formal paper on the completed project.
- iii) Formally and orally present entire project.
- iv) Publish the paper either in the TLRBSE research journal, the web site [www.AstronomyTeacher.com](http://www.AstronomyTeacher.com), a public science fair, or other non-classroom venue as appropriate.

\* Adapted from Liberty USHD Advanced Bio Research course posted at [www.ucop.edu](http://www.ucop.edu).