ARISE: American Renaissance in Science Education

Instructional Materials Guide

Part 1 – Physics

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ARISE Physics

Forward:

This is an interim version of the Volume 1 of a 3-volume "cut and paste" guide to the "Physics First" curriculum. It currently contains only our ideas on the topics that should be taught and the students' skills which need to be developed in the physics course which forms the first of the three science courses of the ARISE sequence.

Your comments would be very welcome. Please send e-mail to Dr. Lederman at lederman@fnal.gov

Curriculum Topics

The topics which have been chosen for the proposed first year of the ARISE high school sequence are those which we believe will best prepare the young minds of freshmen for the chemistry course of the following year. This means that a number of topics found in a "conventional" high-school physics course have had to be excluded. These topics will, we hope, be taken up in the elective physics course that students will take as seniors.

We believe that the topics listed below, done thoroughly, will provide a suitable introduction to a basic science discipline, physics, and also provide a good basis for chemistry. Enrichment of the course according to the teacher's interest or the student's demand is to be encouraged, but not at the cost of leaving out the necessities for understanding the concepts required for chemistry.

Traditional textbooks showing a similar sequencing to this would be:

Serway and Faughn, Giencoli, Bueche. These are all texts used at the college level by non- science majors but they are frequently used in high schools. These texts will be a useful reference for the teacher.

	Main Subject	Specific Topic
Topic 1	Vectors	Displacement Velocity Force Force Table Components
Topic 2	Kinematics	Displacement Velocity Acceleration One and two-dimensional motion
Topic 3	Dynamics	Force Newton's 1st Law Newton's 2nd Law Newton's 3rd Law Friction
Topic 4	Work and Energy	Work Kinetic energy and work-energy theorem Potential Energy Conservation of Mechanical Energy Power The very special role of energy in science

Topic 5	Momentum and Collisions	Center of gravity Momentum and Impulse Conservation of Momentum Collisions in 1-dimension Collisions in 2-dimensions
Topic 6	Circular Motion	Uniform Circular Motion Centripetal acceleration Centripetal force Universal Law of Gravitation Gravity at all locations Satellites
Topic 7	Electric Forces	Electric Charge and Fields Force between charges Electroscope Conduction and Induction The electric field
Topic 8	Electric Potential	Electric Potential Energy Potential Difference Equipotential Battery
Topic 9	Magnetism	Magnetic Field Mapping Earth Magnetic Field Magnetic Field Created by an Electric Current
Topic 10	Electromagnetic Waves	Oscillating Electric and Magnetic Fields
Topic 11	Geometric Optics:	Concept of light Speed of light
Topic 12	Vibrations and Waves	Periodic motion Hooke's Law and elasticity Potential energy Simple Harmonic Motion Wave terminology Wave interaction: reflection And transmission Wave Resonance in a string Transverse and Longitudinal waves Include ripple tank and sound demonstrations as examples of wave behavior.

Topic 13	Relativity	Postulates of relativity Speed of light as limiting speed Simultaneity Moving clocks run too slowly Relativistic length contraction Relativistic mass-energy relationship
Topic 14	Photons	Planck’s discovery Einstein’s use of Planck’s constant Compton Effect
Topic 15	Quantum Mechanics	deBroglie wavelength Wave mechanics versus Classical mechanics Resonance in deBroglie waves The uncertainty principle
Topic 16	The Atom	Atomic structure Electron energy levels A glimpse at chemistry Nucleus Fission and fusion.

Development of Students' Skills

Fred Myers

One of the many advantages of following the sequence of science courses recommended by ARISE is that students' skills can be developed and nurtured as the need for those skills becomes apparent. Since concepts flow logically through each course, a skill once learned is used over and over as interdisciplinary connections are made. Skills that are learned in mathematics and in experimental work lead to an ability to think critically. Making sensible estimates and appreciating fine differences are essential for this kind of thinking and the laboratory is the ideal place to learn these skills.

The level of student mathematical skills is an important issue when implementing a ninth grade physics program. It is important to decide up-front if the students will be grouped heterogeneously or according to their mathematical skills. If you choose the heterogeneous route, general classroom presentations and expectations must be respectful of those students who are not yet proficient with algebra. Differentiated instruction and more advanced mathematical treatments should be provided for those students who are proficient with algebra.

Many schools have found it advantageous to offer ninth grade physics at two different levels. A more advanced level should be available to students who are proficient with algebra, and a separate level should be available for students who have not yet become proficient with algebra.

Some ninth grade physics programs have come under fire because they are called 'conceptual physics'. A quality ninth grade course should emphasize the importance of conceptualizing physics, but no course should be devoid of mathematics. A physics course begs to be both conceptual <u>and</u> quantitative.

Mathematics should always be used in experimentation, and mathematics should frequently be used in problem solving. However, algebraic dexterity should not be the focus. For decades, many physics students have become discouraged because they don't see the forest for the trees. That is, their difficulties and frustrations with algebraic dexterity often cloud their view so much that they do not recognize the power, beauty, and wide applications of the concepts of physics.

<u>Basic Skills and Knowledge</u>

Instruction for the following list of basic skills and knowledge should be embedded throughout this course and throughout all later science courses. It is not recommended that an introductory unit on these basic skills be taught in isolation. Students too often find it uninteresting and boring when taught in this manner, forever tainting their view of physics. Instead, students should receive instruction regarding these basic skills when the need arises and in context with real exploration or learning.

1. Units

Metric prefixes: k, c, m, n
Metric conversions
English/metric conversions
Distinction between derived and fundamental units

2. Measurement Skills

Students will use a variety of instruments to make measurements of the following:

- Length (meter stick, ruler)
- Time (stop watches, strobe devices)
- Mass (triple beam balance, electronic balance)
- Angles (protractor)
- Voltage (voltmeter)
- Current (ammeter)

Students will recognize that there is no such thing as an <u>exact</u> measurement

- Accuracy
- Precision
- Repeatability & fluctuation
- Round measurements to reflect reasonable accuracy
- Percent deviation/error = [Difference/"Accepted"] x 100
- Validity of experimentation

3. Data Tables

Appropriate columnar structure
Clear labeling

4. Graphing Skills

Construct graph from given data (including selection of appropriate graph format, setting up proper and reasonable axes, title, labels, appropriate scale & range, and reasonable data points)
Interpolation
Extrapolation
Conceptual description of slope from visual check of graph
Draw visual (not mathematical) best-fit lines representing the data
Determination of value of slope
Write equation to represent data of straight-line graphs

5. Significant Digits

Significant digits enable communication about measurements
Use of significant digits should be 'reasonable'
Recognize the number of significant digits in a reported measurement
Report a reasonable number of significant digits when measuring
Report a reasonable number of significant digits when performing calculations

6. Other Mathematical Skills

Students will be able to apply a variety of mathematical tools to the investigation of physics:

- Basic calculator functions: +, -, x, /, and √
- Rounding
- Calculate means of a set of values
- Express numbers in scientific notation
- Translate values written in scientific notation to numbers

Perform mathematical functions with numbers written in scientific notation (+, -, x, /, and √)

Use symbols to represent quantities

Solving equations

- Substitute quantity values into equations
- Solve equations for unknown (basic algebra)

Pythagorean Theorem

Characteristics of circles: radius, diameter, circumference