EDUCATIONAL MODULE
BNL/DOE PST Program
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TITLE:

A Scientific Investigation of Soda Froth Decay

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GRADE LEVEL/SUBJECT:

Regents Physics, Advanced Placement (AP) Physics
Grades 11 and 12

CURRICULUM STANDARD AND LEARNING OBJECTIVES:

Students will fulfill the following standards found in the New York State Regents Physics Core Curriculum and learn the skills and concepts associated to each area:

STANDARD 1: ANALYSIS, INQUIRY, AND DESIGN
Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematical Analysis

Key Idea 1:

Abstraction and symbolic representation are used to communicate mathematically.

M1.1 Use algebraic and geometric representations to describe and compare data.

- represent physical qualities in graphical form
- construct graphs of real-world data (scatter plots, line or curve of best fit)

Key Idea 2:

Deductive and inductive reasoning are used to reach mathematical conclusions.

M2.1 Use deductive reasoning to construct and evaluate conjectures and arguments, recognizing that patterns and relationships in mathematics assist them at arriving at these conjectures and arguments.

- interpret graphs to determine the mathematical relationship between the variables

Key Idea 3:

Critical thinking skills are used in the solution of mathematical problems.

M3.1 Apply algebraic and geometric concepts and skills to the solution of problems.

- explain the physical relevance of properties of a graphical representation of real world data

Scientific Inquiry

Key Idea 1:

The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

- develop extended visual models and mathematical formulations to represent an understanding of mathematical phenomena
- clarify ideas through reasoning and discussion

Key Idea 2:

Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

S2.2 Refine research ideas through peer feedback obtained from discussion.

S2.4 Carry out a research plan for testing explanations, including selecting and developing techniques, and recording observations.

Key Idea 3:

The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

S3.1 Use various means of representing and organizing observations (e.g. diagrams, tables, charts, graphs, and equations) and insightfully interpret the organized data.

- use appropriate methods to present scientific information
- identify possible sources of error in data collection and explain their effects on experimental results

S3.2 Apply statistical analysis techniques when appropriate to test if chance alone explains the result.

- examine collected data to evaluate the reliability of experimental results, including standard deviation, line of best fit, and the use of the correct number of significant digits

S3.4 Based on the results of the test and through public discussion, revise the explanation and contemplate additional research.

Engineering Design

Key Idea 1:

Engineering design is an iterative process involving modeling and optimization which is used to develop technological solutions to problems within given constraints.

T1.1 Students engage in the following steps of a design process:

- generate creative solutions, break ideas in to significant functional elements, and explore possible refinements; predict possible outcomes using mathematical modeling techniques; choose the optimal solution to the problem
- perform a test of the solution according to design criteria; record, portray, and logically evaluate performance test results through quantitative, graphic, and verbal means; use a variety of creative verbal and graphic

techniques effectively and persuasively to present conclusions, predict impacts and new problems, and suggest and pursue modifications

STANDARD 2: INFORMATION SYSTEMS
Students will access, generate, process and transfer information, using appropriate technologies.

Key Idea 1:

Information technology is used to retrieve, process, and communicate information as a tool to enhance learning.

1.1 Understand and use the more advanced features of spreadsheets

1.2 Prepare multimedia presentations demonstrating a clear sense of audience and purpose.

- use appropriate technology to gather experimental data, develop models, and present results

STANDARD 6: INTERCONNECTEDNESS: COMMON THEMES
Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Models

Key Idea 2:

Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

2.1 Revise a model to create a more complete or improved representation of the system.

2.2 Collect information about the behavior of a system and use modeling tools to represent the operation of a system.

- use observations of the behavior of a system to develop a model

2.3 Find and use mathematical models that behave in the same manner as the processes under investigation.

- represent the behavior of real-world systems, using physical and mathematical models

2.4 Compare predictions to actual observations, using test models.

- validate or reject a model based on collated experimental data
- predict the behavior of a system, using a model

Patterns of Change

Key Idea 5:

Identifying patterns of change is necessary for making predictions about future behavior and conditions.

5.1 Use sophisticated mathematical models, such as graphs and equations of various algebraic or trigonometric functions.

- predict the behavior of physical systems, using mathematical models such as graphs and equations

5.2 Search for multiple trends when analyzing data for patterns, and identify data that do not fit the trends.

- deduce patterns from the organization and presentation of data
- identify and develop models, using patterns in data

Optimization

Key Idea 6:

In order to arrive at the best solution that meets criteria within constraints, it is often necessary to make trade-offs.

- determine optimal solutions to problems that can be solved using quantitative methods

STANDARD 7: INTERDISCIPLINARY PROBLEM SOLVING

Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Connections

Key Idea 1:

The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science, technology, design, and inquiry into phenomena.

- address real-world problems, using scientific methodology

Strategies

Key Idea 2:

Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

- collect, analyze, interpret, and present data, using appropriate tools

OVERVIEW:

This two day lesson will:

- introduce students to the concepts of linear and exponential decay
- allow students to enhance their laboratory technique and better understand the scientific method by giving them freedom in the design of the investigation
- teach students how to interpret data by mathematical modeling, using a statistical data analysis method
- show students how to use spreadsheet software (Microsoft Excel) in order to manipulate data, create fits and graphs, and interpret results

TIME ALLOTTED:

One 45 minute period and one 90 minute period

VOCABULARY:

Analysis
χ^2 test
Data collection
Degrees of freedom
Experimentation
Exponential decay
Exponential growth
Fitting
Half life
Least squares
Lifetime
Microsoft Excel
Minimization
Modeling
Normalization
Radioactive decay
Scientific method
Solver
Spreadsheet
Uncertainty

RESOURCES/MATERIALS:

- Can of soda at room temperature
- 100 mL graduated cylinder
- Ruler
- Stop watch or wrist watch (with second hand)
- Pen and lab notebook
- Computer with Microsoft Excel
- Baking soda
- Sugar
- Milk
- Egg white
- Ice shavings

PREREQUISITE KNOWLEDGE (ONE DAY):

DAY ONE – INTRODUCTION AND LABORARTORY PREPARATION

PART ONE: INTRODUCTION

- Students should be introduced to the concepts of growth, decay, and lifetime.
- Different types of decay and growth rates, including linear and exponential rates should be shown and interpreted, with corresponding examples. Examples of

exponential rates should include: heat transfer and dissipation, population growth, drug absorption in the body, light attenuation, and in the most detail, radioactive decay.
- Using radioactive decay of parent isotopes into daughter isotopes, the theory of radioactive decay should be explained in detail, explaining the meaning of half life and decay constant, and explaining their relationship.

PART TWO: LABORATORY PREPARATION

- The concept of the scientific method, with each of its components should be covered in detail with the importance of each stage shown, including keeping good records of observations, and data analysis.
- The idea of modeling data to theory by mathematical fitting should be introduced. The meaning of a least squares fit should be explained, as well as the idea of a statistical χ^2 test of the fit.
- Students should have an introduction to Microsoft Excel, learning about spreadsheets and their capabilities. They should be shown how to setup the Excel spreadsheet in order to perform a fit, and also, the Solver routine should be presented. The attached document is a guide to fitting using Excel for teachers.
- Hand out guide for the laboratory, and review vocabulary.

MAIN ACTIVITIES (NEXT DAY):

DAY TWO – PERFORMING THE SCIENTIFIC INVESTIGATION

PART ONE: MEASURING SODA FROTH DECAY

- Distribute soda, graduated cylinders, rulers, and stop watches to students. Have them investigate the soda froth decay using these materials without giving them step by step instructions. Remind them to record all data, observations and methods in their lab notebooks.
- Ask them about the problems they are running into while performing the experiment. Have them come up with ways to adjust their measuring techniques and methods to help overcome these problems. Have them use these adjustments to perform more trials and record all data and observations.
- Have them enter their data into an Excel spreadsheet, and perform a quick graph of data to visually see the general behavior of the froth.

PART TWO: EXPLORING EFFECTS OF VARIOUS SUBSTANCES ON DECAY

- Ask students to brainstorm any other ideas to implement the investigation including changing temperatures, pressures, and adding other substances to the experiment.
- Present the other substances to the students (along with more cans of soda), and have them predict the behavior of the froth when certain substances are added. Then, without specific instruction, have the students perform their own

investigations using the various items, and have them record all methods, observations, and data.
- Have students enter data into an Excel spreadsheet and make a quick graph of the data to visually see results.

PART THREE: ANALYSIS OF MEASUREMENTS

- Looking at the different data graphs, ask students what they think is the behavior of the decay rate for each scenario (linear decay, exponential decay, or neither).
- Have students take their best set of data obtained from investigating the decay of the soda froth (from part one) and analyze it in detail, doing a minimization by least squares fit, and constructing a χ^2 test for both a linear fit and an exponential fit in order to determine which fit best describes the natural behavior.
- Have the students repeat this analysis for a set of data where they investigated the effects of baking soda on decay rate and come up with the best fit function. Also, have the students choose another data set obtained from the investigation of a different substance, and have them analyze it.

PART FOUR: CLASS DISCUSSION (WRAP-UP)

- Students share their own methods, investigations, and findings from the data analysis. The class discusses general conclusions about the (exponential) behavior of the soda froth decay. The class discusses conclusions for the effects of the various substances on the froth decay (e.g. the baking soda produces bubbles while the froth is decaying, making the general trend of the decay of the soda froth linear instead of exponential).
- Students share lessons learned about the experimentation process, the aspects of scientific method, and the importance of data analysis.
- General discussion about the amount and sources of error and uncertainty in the lab, and the effects of error on analysis and results.
- Students share ideas for further investigations, along with their hypotheses.
- Have students record all conclusions, findings, and ideas in their lab notebooks.

EVALUATION:

- Excel spreadsheets and Excel graphs can be evaluated using a rubric that is developed with the class, listing elements that they feel were important and should be included in a quality investigation. The teacher can also assess the spreadsheets and graphs for quality and completeness.
- Students can make power point presentations or poster presentations that can be assessed by both the other students in the class and the teacher, using a pre-constructed rubric. The presentations should include data collected in the experimental process, observations and changes made during the experiment, conclusions developed, and further ideas for investigation.
- Lab notebooks can be exchanged with other students to make comments on their data and experimental procedures. A rubric could be developed with the entire

class on what should be included in an effective and organized lab notebook. The teacher can also assess the lab notebooks for quality and completeness.

- A written assignment can be given where students explain in essay format what they have learned from the lab. This assessment may be a set of guided essay questions focusing on the major concepts of the lab. This assignment should include an explanation of the process of the scientific method, the importance of keeping a good written record of observations and data, the use of data analysis to test hypotheses, their findings, and other possible examinations based on their findings.