TITLE:

Measure Adventure

AUTHOR:

Jennifer Docktor

GRADE LEVEL/SUBJECT:

High School Physics
Grades 11 and 12
50-minute periods

CURRICULUM STANDARDS: AAAS BENCHMARKS. PROJECT 2061

SECTION 1, THE NATURE OF SCIENCE

By the end of the 12th grade, students should know:

1A The Scientific World View:

- No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.

1B Scientific Inquiry:

- Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns.
- Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of data (both new and previously available).

SECTION 9, THE MATHEMATICAL WORLD

By the end of the 12th grade, students should know:

9A Numbers:

- When calculations are made with measurements, a small error in the measurements may lead to a large error in the results.
- The effects of uncertainties in measurements on a computed result can be estimated.

9B Symbolic Relationships:

- Any mathematical model, graphic or algebraic, is limited in how well it can represent how the world works. The usefulness of a mathematical model for predicting may be

limited by uncertainties in measurements, by neglect of some important influences, or by requiring too much computation.
- Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another.

SECTION 12, HABITS OF MIND

By the end of the 12th grade, students should know:

12B Computation and Estimation:
- Trace the source of any large disparity between an estimate and the calculated answer.
- Consider the possible effects of measurement errors on calculations.

12D Communication Skills:
- Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.
- Use tables, charts, and graphs in making arguments and claims in oral and written presentations.

OVERVIEW:

This 3-day lesson will introduce students to the importance of scientific measurements, and the various methods used by scientists to collect data. They will become familiar with the concepts of direct measurement, indirect measurement, accuracy, and precision. Students will have the opportunity to experience measurement first-hand in a laboratory investigation, and apply what they have learned during a discussion on special relativity concepts.

PURPOSE:

The purposes of this module include:
- To introduce students to the methods for direct and indirect scientific measurement
- To provide students experience collecting and analyzing data, particularly making scientific measurements
- To familiarize students with laboratory technique using CBL motion detectors and calculators
- To give students a hint of special relativity topics that will be covered in later chapters

LEARNING OBJECTIVES:

Students will be able to:
- Distinguish between the methods for direct and indirect scientific measurements, and identify concrete real-world applications of each.
- Explain the difference between accuracy and precision in measurements.

- Gain a better understanding of the 'language of physics' that is used in experimentation (tables, graphs, and equations).
- Use graphs and data analysis to examine the relationships between measured physical quantities.
- Use CBL laboratory equipment to make scientific measurements.
- Explain in general the concept of time dilation in special relativity.

VOCABULARY:

direct measurement
indirect measurement
accuracy
precision
data analysis
special relativity
time dilation

RESOURCES/MATERIALS:

Free-fall lab:
Meterstick
Rectangular wooden block
C-clamp
CBL
CBL motion detector
Graphing calculator with link cable
Support stand and clamp
Thin foam pad
Stopwatch

Monte Carlo technique lab:
Copies of circles handout
Sheets of carbon paper
Marbles or ball-bearings
Calculator
Ruler

PREPARATORY ACTIVITIES:

Previous Knowledge:

- This module is intended for use in introductory sections of a high school physics course. Students should already have a clear understanding of what physics is, the scientific

method and models, SI standard of measurement, dimensional analysis, and significant figures.
- Students may or may not have prior experience using CBL lab equipment, so an introductory demonstration of these tools might be necessary at the discretion of the instructor.
- These lessons are part of a larger unit on "The Science of Physics." There are no required preparatory activities aside from those of previous lessons.

MAIN ACTIVITIES:

DAY ONE – DIRECT/INDIRECT MEASUREMENT, MONTE CARLO INVESTIGATION

10 minutes
- Students speculate on the difference between direct and indirect measurement, and how the methods for each might differ.
- Introduction to the lab.

40 minutes
- Indirect Measurement lab investigation by students in pairs: Monte Carlo technique experiment.

DAY TWO – ACCURACY AND PRECISION, FREE-FALL INVESTIGATION

5 minutes
- Brief discussion/wrap-up about yesterday's lab.

5 minutes
- Students look up the terms accuracy and precision in their text, and write them into their notes.
- Introduction to the lab.

40 minutes
- Free-fall lab investigation by students in groups of 3-4, depending on CBL equipment availability.

DAY THREE – MEASUREMENT APPLICATIONS, SPECIAL RELATIVITY

20 minutes
- As lab groups, students present their results from the previous day's free-fall investigation.

15 minutes
- Students complete the think-pair-share model to come up with real-world applications of both direct and indirect scientific measurement techniques. First they brainstorm ideas independently, then they share them with a partner, and later the entire class.
- If computers are readily accessible, students could also use these to further investigate their selected applications prior to class presentation.

15 minutes

- Students engage in a very general introduction to topics of special relativity that will be covered in later chapters.
- They read and discuss the concept of time dilation using light clocks in a moving train.
- A handout describing length contraction and the pole in the barn paradox is given to students. They must work in teams to hypothesize an explanation for or solve the paradox.

EXTENSIONS:

Students who are interested in learning more about indirect measurement Monte Carlo techniques used by collider detectors in high-energy particle physics can refer to a website from Fermi National Accelerator Laboratory at http://www.fnal.gov/pub/inquiring/physics/index.html

Students wishing to explore special relativity concepts further can refer to the following websites:

Special relativity:
http://casa.colorado.edu/~ajsh/sr/sr.shtml

NSTA scilinks: Relativity of time
www.scilinks.org code: HF2025

Use data from a Fermilab experiment to investigate special relativity!:
http://www-ed.fnal.gov/data/phy_sci/relativity/index.shtml

Readings on Relativity:
"Relativity: The special and general theory" by Albert Einstein
"The Meaning of Relativity" by Albert Einstein