DETERMINING MASS WITH A MODEL CALORIMETER
FOR THE TEACHER

DESCRIPTION
In this activity students explore how to determine mass using indirect observation. They build a mass calorimeter model that includes an accelerator, collimator and detector, calibrate the device and use it to determine the mass of an unknown object.

This analogy can fit into classroom discussions and projects that center on:
- Energy
- Work
- Particle detectors

STANDARDS
National Science Education Standards (U.S. National Research Council)
- Teaching Standards:
  - A: Plan an inquiry-based science program.
  - D: Design and manage learning environment.
- Content Standards:
  - A: Science as inquiry
  - B: Physical science
  - E: Science and technology
- Program Standards:
  - B: Developmentally appropriate, interesting, and relevant
  - C: Coordinated with mathematics program

LEARNING OBJECTIVES

PRIOR KNOWLEDGE
Before starting this activity, the students must understand the principles behind the function of a calorimeter. Through the measurement of energy deposition (or momentum) in the layers of a detector, scientists can determine which particles are present. The amount of energy deposition is related to the mass and velocity of the particle.

BACKGROUND MATERIAL
Students build a model of a particle physics calorimeter using common materials. The students roll balls of various masses down an inclined plane. The balls will collide with/move an arrangement of blocks. Students record the mass of the ball and the number of blocks that it displaced. Students use this information to predict the mass of an unknown ball.

We suggest that you use a PVC pipe for the inclined plane and rigid balls. Rubber balls store some of the collision energy in deformation. We also suggest using light, wooden or prepainted Styrofoam blocks. To ensure that the ball reaches the target, you can “collimate” the beam by making a channel between two parallel meter sticks.

Student groups need:

Several rigid balls with various/known masses
1 or more rigid balls with unknown mass
"Blocks" – for example, Project Bricks by FloraCraft or balsa cubes
Materials for an inclined plane and collimator
Graph paper

IMPLEMENTATION

Framework for Inquiry

Hook/Discovery/Observation

- Newton's cradle
- ATLAS/CMS videos
- Row of dominos knocked over
- How can physicists determine the type of particles being produced in their detectors?

Questions from Observation

- Student generated
- Brainstorm (accept all) – "Why" questions are OK here.
- Categorize – Testable vs. not testable

How does *"IV"* affect *"DV"*?

- Possible IVs: Size of particle, shape of particle, speed of particle, medium through which the particle travels . . .
- Possible DVs: How far the particle travels, how many objects does it displace . . .

Hypothesis – Proposed answer to the research question based on limited evidence. "A more massive sphere will displace more of the blocks than a lower mass sphere. Gathering this data should allow the determination of a sphere of unknown mass."

Experiment on Own

- Teacher questions to guide student experiences
  - Whole classes vs. small group – What can you do to limit the number of variables present? What are you trying to measure? What is the best way to display and analyze numerical data?
  - Provide support mechanisms while walking around the classroom. Use questions to head off unproductive research.

Share Results/Revise Procedures

- Products may include graph of mass vs. distance with the unknown mass interpolated from the curve.

Experimentation Revised

- What worked? What did not work?

Draw Conclusions Based on the Evidence

- Does the evidence support or fail to support your hypothesis?

- How close is close enough experimental uncertainty, special factors which may have affected your research?

Communication - Summarize Conclusions

- Reflection – What do you know based on the evidence of your research?
- Next Questions – What other designs might be useful?
- Making Connections to Particle Physics – Function of a calorimeter, ability to analyze event displays to determine which particles are present in the detector after a collision
- Relevance in school and in life –Accelerators/detectors used in cancer treatment and diagnostic procedures came from particle physics research and experiments using detectors.

ASSESSMENT

USE A SIMPLE DETECTOR TO DETERMINE THE UNKNOWN MASS OF A BALL

BACKGROUND INFORMATION

Scientific instruments must be calibrated. This process involves observing how the detector responds to known input. This generates a "response curve." Scientists compare later results to this response curve.

Use the materials to investigate how the number of displaced blocks depends on the mass of the ball. You should be able to estimate the mass of your unknown ball using the results of this investigation.

Questions to consider include:

- How many times should you roll a ball down the incline before you record the number of dominoes that it displaces? Do all of these rolls "count?" Which ones do? Why?
- Should you release any particular ball from the same height on each roll?
- What mass did you find for your unknown? How confident of that are you? What could you do to increase your confidence?