Classroom Lesson Development

Title of Lesson: Impact Damage Assessment Lab

RET Project Connection: Effect of Impact and Heat Exposure on Fiber Reinforced Al-Metal Matrix Composites

RET Teacher: Mike Maloney
School: Somerville High School
Town/District: Somerville, Massachusetts
Subject(s) Taught: Physics AP, Physics Honors, Tech Physics

Subjects Covered: Physics, Mechanics
Grades Appropriate: 10, 11, 12 (*algebra needed*)
Lesson Duration: 1-2 class periods

Goals/Objectives: (Student will)

1. Be exposed to how different areas of physics are used together to solve a problem.
2. Analyze the impact of a mass on different materials in terms of impact speed, change in momentum, work done, impact force and impact time.
3. Create, setup, complete, and analyze laboratory procedures.
4. Determine Impact speed based on Conservation of Energy.
5. Determine Work done in collision from Work-Energy Theorem.
6. Determine Impact Force from definition of work.
7. Look at results to make a conclusion about their experiment.

Background Information:

Collisions happen everywhere in life. Billions of dollars are spent to make collisions safer. Major factors in how safe a collision is the Impact time and Impact Displacement. Great Impact displacements and times allow smaller forces to be applied during collisions, resulting in safer and more survivable collisions. This lesson was developed to allow students to see how different materials act when impacted by a certain object (in this case a steel ball). Materials such as steel will deform very little, while materials like clay, wood, or Styrofoam will have much deeper deformations. Many students either believe that the collision with the clay/wood/foam is a much worse collision (bigger forces are applied) because there is more damage or that all cases have the same forces applied. However, the opposite is true, the steel feels much higher a force because the impact displacement (and time) is much smaller.

Essential Questions:

1. What makes a collision safe or dangerous?
2. What variables change from collision to collision?
3. What variables affect the force in collisions?
4. How does material type affect these factors?
5. How can collisions be analyzed?

Links to Massachusetts Physics Frameworks:

1.3 Distinguish between, and solve problems involving, velocity, speed, and constant acceleration.
1.7 Interpret and apply Newton's second law of motion to show how an object's motion will change only when a net force is applied.
2.1 Interpret and provide examples that illustrate the law of conservation of energy.
2.2 Provide examples of how energy can be transformed from potential to kinetic.
2.3 Apply quantitatively the law of conservation of mechanical energy to simple systems.
2.4 Describe the relationship among energy and work both conceptually and quantitatively.

Materials Required:

- PVC pipe and adhesive to build drop apparatus with
- Steel ball(s) to drop on specimens
- Various specimens of roughly the same size (don't have to be exact)
  - MMC, steel, aluminum, plastic (maybe), Styrofoam, softwood, hardwood, etc
- Some type of stage to arrange samples in (could be fabricated)
- Modified calipers to measure the dimple depth.
- Vernier Force Plate/LabPro/PC (to use for extension if desired)
- Meter stick or tape measure

Lesson Development:

1. Review with students the concepts of work and energy. Talk to them about collisions, maybe show some videos of car crashes or do some demonstrations with the materials they will be using what happens in collisions.

2. Have students work in groups to think about the essential questions posed above.

3. Students will be posed with a problem of evaluating damage on a specimen by a metal ball via impact depth. They will be given materials to use and be asked to come up with a procedure on their own in groups, and a way to analyze any data collected during the experiment. The materials will drive and limit what they can do, but how to use the materials, number of trials, what to measure, how to measure, will be determined by the students in groups and then reviewed by the instructor. The students will then make a hypothesis, and use their materials to carry out their procedure.

4. After the students collect data on several different materials, they will analyze and use their data to calculate
   - Initial Potential Energy (PE = mgh)
   - Impact Kinetic Energy (Conservation of Energy; PE + KE = constant)
   - Impact Velocity ($KE = ½\ m\ v^2$)
   - Work Done ($W = \Delta KE$)
   - Force of Impact ($F*d = ½\ m\ v^2$)
   - Averages and Standard Deviations

5. Once the data is analyzed, the students will review their data and determine answers to the essentials questions that were posed above, and try to determine what affects a collision, and how different materials changes what goes on during a collision, and prepare a standard lab report based on and including their hypothesis, background, data, results, analysis, and conclusions.

Extension: If resources are available, students can place their specimens on top of a Vernier force plate and measure the force that is transmitted to the plate during the collision. They can then see if this transmitted force correlates to any other their calculated results. In a perfect world all the force of the collision should be transmitted, but energy is lost due to sound, heat, bouncing, etc so the force plate will not show the exact calculated results, but should still show the trends that materials with more deformation should have smaller transmitted forces.

Concerns:

- o Students should wear safety goggle during impacts. Some may need help constructing setups.
- o The equation $F*d = \Delta KE$ assumes a lot that may not be true in real life. If the students sample bounces, or has some elastic deformation their results will not be entirely collect, but if you use materials that stay deformed (metal, wood, clay, Styrofoam) and not materials that retain shape (plastics, rubber, foam, etc) the dimple depth should be able to be measured and trends should be correct, if the numbers are not exactly correct.

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