Fermilab Education and Public Engagement Activity Template

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Activity Name Collision Crash Course	
Grade Level 11	**Unit Topic Connection** Momentum

The Hook

(Write a two- to three-sentence introduction, including thought-provoking questions related to the activity.)
Does mass matter? What happens when two subatomic particles collide at near-light speed? Is it different from when two objects of everyday mass collide? What happens to both particles after they collide? How are collisions related to Newton's Laws of motion and kinematics?

Scenario/Background Information

(Write a few paragraphs with further information about the activity. What is the problem that is to be investigated? Explain the problem/challenge in terms of a real-world situation that is to be solved.)

The activity was sparked by an image of a particle after a collision. What conclusions can we gain from this? What can we infer about the scenario before the collision?

These are the questions that came to mind for 3 physics teachers designing the lesson. The challenge we encountered was 'How could we prepare 1st-year HS physics students to analyze this scenario effectively?' We decided on a scaffolding method to build students' skill in working through conservation of momentum problems. We will start with students making qualitative observations. From there, students will begin investigating conservation of momentum and performing calculations. Finally students will begin using the skills they've developed and apply them to real-world engineering and cutting-edge particle physics.

Safety

(Explain what cautions students should take during the activity.)
Be careful with massive objects, protect eyes if necessary and avoid collisions between things that may produce small pieces that could fly towards you. Ensure that you have enough space for the collision to occur.

Student Question/Problem/Challenge

(Explain what the student teams will do in their activity.)
How can we use conservation of momentum to analyze the results of particle collisions?

Learning Goals/NGSS Performance Expectations

(Explain what students will learn during the activity, including practices and content.)

- Students will be able to explain how mass and velocity are related to collisions.
- Students will be able to differentiate between different types of collisions
- Students will be able to connect the physics of collisions to their prior knowledge of kinematics and Newton's Laws of Motion
- Students will be able to apply what they learned regarding collisions to real-world example of both car crashes (most are new drivers) and to the NOVA neutrino project at FermiLab

What will you need?

Supplies	Setup
• Household items (tennis ball, billiard balls, marbles, etc) • School-issued Chromebook	minimal Tips • Students should be specific and write down everything they see during their collisions • Students should continually be thinking about how their at-home collisions relate to real world collisions.

Process

(Write a process that will **guide the facilitation** of the activity. Remember that the point of the activity is for the students to think about what **they** need to do to achieve their goals.)

Students are 'hooked' by a discussion on particle accelerators/subatomic particles. This leads into a discussion of collisions. Then the 4 activities listed below will be performed sequentially and aided by class discussion as well as additional resources and supports.

The end point of the activity is to use a basic understanding of conservation of momentum to analyze collisions in a particle accelerator. A typical HS student needs some scaffolding to reach this end point. Students would engage in the following activities in order

1. Qualitative Collision Activity: Students use objects found around their home (marbles, tennis balls, basketballs, hot wheels cars etc) and make qualitative observations about collisions involving masses traveling at a variety of velocities.
2. Quantitative Collision Activity: Students then use an online simulation to collect data and predict the outcomes of various different potential collisions. Students perform calculations using the $p = \Delta mv$ and conservation of momentum.
3. Real-world Collision Lab: Students use an online resource to learn more about momentum and also begin to use momentum concepts when exploring engineering challenges like making cars more safe.

4. Assessment/Culminating Activity: Students examine collisions in a particle accelerator. Real-world data is used from Fermilab trials. Students may have to use the conditions after a collision to predict conditions before the collision or vice-versa.

Wrapping it up

(Provide suggestions for classroom discussion and pacing from lesson to lesson as well as connecting to the curriculum unit topic and learning goal.)

Timing: 5-7 class periods (45 min each)

Discussions and connections:

- A discussion on the qualitative nature of collisions and using that to predict how objects will interact.
- An introduction to momentum calculations and conservation of momentum
- A connection to engineering, driving safety and careers

Assessment

(This activity may serve as a performance assessment for a unit. How can the students apply their content knowledge and be aware of the many practices they utilized during the challenge activity? Provide suggestions on how to assess student success. Suggestions may include student logbooks, including notes, data and reflection on their thinking.) ● Student logbooks/notebooks will be used to record initial collision observations between objects. They can also upload videos of their collisions between everyday objects. ● Defend the claim that quantum particles behave the same way during and after collisions as objects of everyday masses do (CER) ● Watch the Physics of Car Crashes from the National Highway Safety Institute and write a summary/reaction that discusses how momentum and collisions pertain to vehicle safety. ● Problem-solving assessment that solves for unknown momentum quantities can also be included.

Standards Connections (Connect to learning goals/performance expectations.)

NGSS Disciplinary Core Ideas	**NGSS Science and Engineering Practices**	**NGSS Crosscutting Concepts**
PS2.A: Forces and Motion Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside	Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1)	**.** (HS - PS3-1) Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)

the system. **(HS-PS2-2),(HS-PS2-3)** (HS-PS1-1),(HS-PS1-3) (HS-PS1-3) . (HS-PS3-1) HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.		

CCSS Math	**CCSS ELA**
CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them. CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.	N/A
SEL Understanding how collisions relate to driving and how to avoid car accidents is an important SEL component	**CTE** The design, engineering, manufacture of safety items like football helmets, car seats and crumple zones for cars.
Other	

Resources and References

(List any useful links for teacher background information. List student resources that may be needed.)

We are one Fermilab
https://news.fnal.gov/wp-content/uploads/2018/10/we-are-one-fermilab.jpg

How Particle Physics Discovery Works
https://www.fnal.gov/pub/science/particle-physics-101/how-works.html

Fermilab Ecology
https://ecology.fnal.gov/

NGSS - Science and Engineering Practices https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Science, Technology, Engineering and Mathematics Career Cluster Knowledge and Skill Statements (2008)
https://cte.careertech.org/sites/default/files/K%26S-CareerCluster-ST-2008.pdf

CCTC - Career Ready Practices
https://cte.careertech.org/sites/default/files/CareerReadyPractices-FINAL.pdf

Project Lead the Way, Engineering Design https://www.pltw.org/our-programs/pltw-engineering-curriculum

5Es
https://ngss.sdcoe.net/Evidence-Based-Practices/5E-Model-of-Instruction

Claim, Evidence, and Reasoning

- **BSCS Scientific Explanation Tool - https://www.amnh.org/content/download/146458/2328830/file/Explanation_Tool_MASTER.pdf**
    - **Rubric https://www.amnh.org/content/download/146460/2328840/file/Explanation_Tool%20RUBRIC.pdf**
- **Scientific Argument Tool - http://sepuplhs.org/pdfs/Argument_Tool_MARCH2016.pdf**
    - **Rubric - http://www.argumentationtoolkit.org/uploads/2/1/4/1/21417276/evidence_rubric.pdf**
- **Sentence Starters for CER - http://www.thinksrsd.com/wp-content/uploads/2014/02/CER-Sentence-Starters-CER.pdf**
- **NSTA Resources on CER - https://learningcenter.nsta.org/mylibrary/collection.aspx?id=GBdqFKABr0U_E**