INSTRUCTIONAL DELIVERY STRATEGY

LESSON PLAN

OVERVIEW:

The Facility for Rare Isotope Beams (FRIB) at Michigan State University is a U.S. Department of Energy Office of Science (DOE-SC) user facility, with user facility operation supported by the DOE-SC Office of Nuclear Physics. At FRIB, scientists study rare isotopes to better understand the properties of atomic nuclei, nuclear astrophysics, and applications for society in medicine, security, and technology.

This lesson introduces students to the physics and research concepts explored at FRIB through an interactive game that models isotope production and acceleration.

INTRODUCTION:

FRIB discovers new knowledge at half the speed of light. This lab helps us understand how stars make elements, how atoms are built, and how we can use this knowledge to improve our world. In today's lesson, you'll explore these big ideas through a **fast-paced, interactive game designed by students and researchers at MSU** where you'll become a virtual ion speeding through an accelerator—just like at FRIB! **Play Isotopolis Racer in a laptop/desktop browser.**

LEARNING OBJECTIVE:

By the end of this lesson, students will be able to:

- Describe what isotopes are and why they matter in science and society.
- Understand how energy and acceleration affect particle behavior.
- Design and test a model in the form of a physics-based game.
- Explain how scientists use particle accelerators to study atomic structure and the universe.

INSTRUCTIONAL ACTIVITIES (Warm-Up, 5–10 mins):

- **Discussion questions** (project on board or handout):
  1. What do you know about atoms?
  2. Have you heard of isotopes?
  3. How do you think scientists explore invisible things like atomic particles?

Quick video or animation (2–3 minutes) showing FRIB in action or a particle accelerator in motion (youtu.be/P4rG-5y9ums).

MATERIALS/RESOURCES

- **Game** (computer with internet accessibility)
- Isotope cards or digital database (FRIB/DOE resources)
- Screen for warm-up video
- Whiteboard/chart paper for strategy notes
- Handouts for reflection and isotope categories
- www.nndc.bnl.gov/nudat3/

MODIFICATION/DIFFERENTIATION:	SAFETY AND PRACTICALITY:
Visual learners: Include diagrams of atoms, isotopes, and accelerator rings. **Kinesthetic learners**: Use physical movement in a gym or open space to simulate acceleration paths. **Struggling readers/writers**: Use symbols and images on isotope cards and allow oral reflection responses. **Advanced students**: Encourage design of their own isotopes or game extension rules.	**Space for movement:** If physical movement is involved, ensure safe, open space and clearly marked game zones. **Technology access and backup plan:** If internet access is limited, provide screenshots or pre-downloaded gameplay videos for observation and discussion. **Behavior expectations:** Emphasize respectful behavior and safe distances when playing movement-based parts of the game.

ESSENTIAL QUESTIONS:	ASSESSMENT METHODS:
At FRIB, researchers explore big questions like: 1. How are elements formed in stars? 2. What are the building blocks of matter? 3. How can science help us in everyday life? 4. How do scientists use models (like games!) to test ideas?	• Class discussion and Q&A responses • Observation during game for use of strategy and scientific thinking • **Exit ticket:** "What is one thing you learned about isotopes today?" • Optional: Design-your-own-isotope extension or short quiz on types and uses of isotopes

ENHANCEMENT ASSESSMENT: Design challenge

Challenge prompt:
Now that you've **experienced and evaluated** the game as a model for how isotopes are created through acceleration and energy, it's time to become a **scientist and a game designer!** Your task is to **analyze the game mechanics and learning goals**, then propose thoughtful innovative improvements that enhance both the gameplay and the educational value and present to the class.

ANALYSIS AND REFLECTION: Digging deeper	
Connecting Gameplay to Nuclear Science.	1. Why are they making rare isotopes? 2. How many protons/neutrons did your racer have? 3. How many did your resulting nucleus have? 4. Why do you have to go fast to make a rare isotope?

Standards Alignment Table: FRIB Physics Game Lesson

Subject Area	Standard Code	Standard Description	Connection to Lesson
Science (NGSS)	MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored.	Students model energy transfer and motion in particle acceleration.
	MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process for optimal design.	Students reflect, redesign, and test their game models for effectiveness.
	MS-ETS1-1	Define criteria and constraints of a design problem to ensure a successful solution.	Students define the rules and outcomes for improving the isotope simulation.
Math (CCSS-Math)	6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a relationship between two quantities.	Students discuss ratios of successful isotopes to attempts; speed/distance relationships.
	7.RP.A.2	Recognize and represent proportional relationships between quantities.	Analyze how acceleration and speed affect isotope creation probabilities.
	6.SP.B.5	Summarize numerical data sets in relation to their context.	Students collect and analyze game data to determine success rates and improvement strategies.
	8.F.B.4	Construct a function to model a linear relationship between two quantities.	Graph speed vs. isotope success; analyze patterns to draw scientific conclusions.
	MP.4	Model with mathematics.	Students apply math to simulate real-world scientific principles through game mechanics.

Subject Area	Standard Code	Standard Description	Connection to Lesson
Engineering / Technology (NGSS ETS)	MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet criteria.	Students compare design changes and predict impact on game learning outcomes.
ELA (CCSS-ELA)	W.7.1	Write arguments to support claims with clear reasons and relevant evidence.	Students justify design improvements in written reflections or presentations.
	SL.7.4	Present claims and findings, sequencing ideas logically and using appropriate facts and descriptions.	Students present their design proposals to peers, using evidence from gameplay and science concepts.
21st Century Skills	N/A	Critical Thinking, Collaboration, Communication, Creativity	Embedded through the design challenge, teamwork, and reflection activities.

VOCABULARY WORD	DEFINITION
Acceleration	The process of speeding up—like how ions move faster in a particle accelerator.
Application	A real-world use of a science idea—like using isotopes in medicine or technology.
Astrophysics	The branch of science which studies how stars, galaxies, and the universe work.
Atom	Objects (your body, a chair, a phone) are made of atoms.
Collision	When two particles or objects strike one another. In the game, collisions with the target at the end of the race are necessary to form new isotopes.
Elements	Materials made of atoms with a specific number of protons. (For example, atoms with 6 protons are the element carbon)
Energy	The ability to do work or cause changes; in physics, it's what powers motion and reactions.
Ion	An atom that has gained or lost electrons, giving it a positive or negative charge.
Ionization	The process of giving an atom a charge by adding or removing electrons.
Isotope	A version of an atom with the same number of protons but a different number of neutrons.
Iteration	Making small changes to improve something, like updating your game design.
Model	A simplified version of something scientists use to understand or explain it (like your game!).
Nucleus	The center of an atom, made of protons and neutrons.
Optimization	Making something work as well as possible, such as making a strategy to win the game.
Particle accelerator	A machine that speeds up particles, like ions, to study their behavior and create new isotopes.
Potential energy	Stored energy based on an object's position/arrangement.
Rare isotope	A type of atom that isn't common on Earth. Rare isotopes can be made in labs like FRIB or inside stars during explosions.