Unit Theme/Name: Impulse, Momentum, and Accident Reconstructions Class/Grade: Physics/10-12

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Learning Objectives

NGSS Student Expectations: students who demonstrate understanding can...

- HS-ETS1-2. **Design a solution** to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-PS2-1. Analyze data to support the claim that **Newton's second law of motion** describes the mathematical relationship among the net force on a macroscopic object, its mass, and its **acceleration**. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]
- , 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. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]
- , HS-PS2-3. Apply scientific and engineering ideas to **design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision**.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

NGSS Disciplinary Core Ideas

- **Both physical models and computers can be used** in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)
- , **Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object**. (HS-PS2-2)
- **Newton's second law accurately predicts changes in the motion** of macroscopic objects. (HS-PS2-1)

NGSS Crosscutting Concepts

- **Algebraic thinking** is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4)

- ~~The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5)~~
- Science and engineering complement each other in the cycle known as research and development **(R&D**). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (HS-ESS1-2),(HS-ESS1-4)
- ~~Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)~~
- ~~Science assumes the universe is a vast single system in which basic laws are consistent. (HS-ESS1-2)~~

NGSS Science and Engineering Practices

- **Plan and conduct an investigation** individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-ESS2-5)
- **Create a computational model** or simulation of a phenomenon, designed device, process, or system. (HS-ESS3-3)!
- ~~Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)~~
- ~~Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS1-1)~~
- ~~Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)~~
- **Communicate scientific ideas** (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3)
- **Theories and laws provide explanations in science**. (HS-PS2-1),(HS-PS2-4)
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Common Core

- English Language Arts
  - **Follow precisely a complex multistep procedure when carrying out experiments**, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
  - **Determine the meaning of symbols, key terms, and other domain-specific words** and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.
  - ~~Integrate and evaluate multiple sources of informationpresented in diverse formats and media (e.g.,quantitative data, video, multimedia) in order toaddress a question or solve a problem~~
  - By the end of grade 12, **read and comprehend science/technical texts** in the grades 11–12 text complexity band independently and proficiently.
  - **Write informative/explanatory texts**, including the narration of historical events, scientific procedures/experiments, or technical processes.
  - **Produce clear and coherent writing** in which thedevelopment, organization, and style are appropriateto task, purpose, and audience.
  - Develop and strengthen writing as needed by **planning, revising, editing, rewriting**, or
- Mathematics
  - NQ: **Use units as a way to understand problems and to guide the solution of multi-step problems**; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
  - Represent and model with vector quantities.
    - 1. (+) **Recognize vector quantities as having both magnitude and direction**. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).
    - 2. (+) **Find the components of a vector** by subtracting the coordinates of an initial point from the coordinates of a terminal point.
    - 3. (+) **Solve problems** involving velocity and other quantities that can be represented by vectors.
  - 4. (+) Add and subtract vectors.
    - ~~a. Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum~~
- Technology
  - **Demonstrate use of intermediate features in word processing application** (e.g., tabs, indents, headers and footers, end notes, bullet and numbering, tables).
  - **Apply advanced formatting and page layout features when appropriate** (e.g., columns, templates, and styles) to improve the appearance of documents and materials.
  - **Highlight text, copy and paste text**
  - **Use the Comment function** in Review for peer editing of documents
  - **Use spreadsheets** to calculate, graph, organize, and present data in a variety of real-world settings and choose the most appropriate type to represent given data
  - **Enter formulas and functions**; use the auto-fill feature in a spreadsheet application
  - **Create presentations** for a variety of audiences and purposes with use of appropriate transitions and animations to add interest
  - **Comply with the district's Acceptable Use Policy** related to ethical use, cyberbullying, privacy, plagiarism, spam, viruses, hacking, and file sharing.

trying a newapproach, focusing on addressing what is most significant for a specific purpose and audience.

- **Use technology, including the Internet, to produce,publish, and update individual or shared writing products** in response to ongoing feedback, including new arguments or information.

~~of two vectors is typically not the sum of the magnitudes.~~

  - b. **Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum.**

- A-REI: **Explain each step in solving a simple equation** as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.
- ~~G-SQRT: Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.~~
- ~~7. Explain and use the relationship between the sine and cosine of complementary angles~~

School Wide Learning Outcomes

Agency

~~1 or~~ Emerging	~~2 or~~ Developing	~~3 or~~ Proficient	~~4 or~~ Advanced
Identifies challenges, failures, or setbacks, but does not describe reactions to them (i.e. giving up or trying harder)	Identifies challenges, failures, or setbacks and describes reactions to them (i.e. giving up or trying harder)	Identifies challenges, failures, or setbacks and reflects on how reactions to them (i.e. giving up, trying harder) affect process, product, or learning	Reflects on personal or academic growth from challenges, failures, or setbacks as well as why and how reactions (i.e. giving up or trying harder) affect the product, process, and learning
Completes few benchmarks and class assignments and may resist or struggle to use resources and supports (i.e. study groups, teacher support, workshops, tutorials)	Completes some benchmarks and class assignments; and, only when forced to, or at the last minute, uses resources and supports (i.e. study groups, teacher support, workshops, tutorials)	Usually completes polished benchmarks and class assignments by using resources and supports when necessary (i.e. study groups, teacher support, workshops, tutorials)	Achieves personal best work on almost all benchmarks and class assignments by setting goals, monitoring progress, and using resources and supports (i.e. study groups, teacher support, workshops, tutorials)
Rejects feedback and/or does not revise work	Sometimes shows evidence of accepting feedback to revise work, but at times may resist when it's difficult	Consistently shows evidence of accepting and using feedback to revise work to high quality	Consistently shows evidence of actively seeking, identifying, and using feedback to revise work to high quality
1……..2……..3	4……..5……..6	7……..8	9……..10

Collaboration

~~1 or~~ Emerging	~~2 or~~ Developing	~~3 or~~ Proficient	~~4 or~~ Advanced
Shows little interest in the ideas of others	Listens with partial interest in the speaker's message providing sporadic verbal/ nonverbal feedback to indicates some understanding or agreement	Listens with interest to the ideas of others providing verbal or nonverbal feedback to signal understanding or agreement	Thoroughly prepares for conversations having read and researched the topic
· At times, addresses others with disrespectful language or tone.	· Usually address others with respect, with minor lapses	-Responds to different ideas or opinions with diplomacy · Addresses others with respect and sensitivity to cultural or language background · Works to resolve conflict through productive discussion and consensus building	In addition, - Shows appreciation for positive and constructive feedback.
- Monopolizes “air time” or frequently interrupt other speakers	- Shares “air time” by allowing others to speak	- Shares “air time” and takes care not to interrupt or cut off others	In addition, · Works to make sure everyone knows what needs to be done
Provides no positive feedback or unhelpful negative feedback	Provides intermittent constructive feedback to team members	· Provides positive and constructive feedback to team members	-Actively encourages and motivates others to attain high levels of achievement
-Devotes less time and effort required to ensure team benchmarks and due dates are met	-Devotes the time and effort required to ensure team benchmarks and due dates are met	· Devotes the time and effort required to ensure team benchmarks and due dates are met and that work is done to a high standard - Supports others to complete necessary work and ensure the team’s success	-Actively encourages and motivates others to attain high levels of achievement
· Has difficulty describing the short and long-term tasks of the team’s work	· Can generally describe the short and long term tasks of the team’s work with some confusion	· Can clearly and specifically describe the short and long term tasks of the team’s work	In addition, · Works to ensure all team members understand the short and long term tasks
1……..2……..3	4……..5……..6	7……..8	9……..10

Written Communication

~~1 or~~ Emerging	~~2 or~~ Developing	~~3 or~~ Proficient	~~4 or~~ Advanced
-Ideas and evidence are disorganized, underdeveloped, or loosely sequenced, making relationships unclear	-Ideas and evidence are organized but not sufficiently developed or logically sequenced to show relationships	-Ideas and evidence are sufficiently developed and sequenced to show relationships	-Ideas and evidence (including claims and counterclaims, as appropriate) are developed and logically sequenced to show clear relationships
-Transitions/section headings are missing, unclear, or confusing	-Transitions/section headings are used sporadically, awkwardly, or in a formulaic manner	-Transitions/section headings connect ideas with minor lapses	-Transitions/section headings connect ideas
-Language, style, and tone are inappropriate to the purpose and audience*	-Language, style, and tone are mostly appropriate to the purpose and audience with some lapses*	-Language, style, and tone are appropriate to the purpose and audience with minor lapses*	-Language, style, and tone are appropriate to the purpose and audience*
-Attempts to follow the norms and conventions of writing in the discipline/genre with major, consistent errors** (e.g. lab report format, showing math, units, be concise)	-Follows the norms and conventions of writing in the discipline/genre with some errors** (e.g. lab report format, showing math, units, be concise)	-Follows the norms and conventions of writing in the discipline/genre with minor errors** (e.g. lab report format, showing math, units, be concise)	-Follows the norms and conventions of writing in the discipline/genre** (e.g. lab report format, showing math, units, be concise)
-Has an accumulation of errors in grammar, usage, and mechanics that distract from or interfere with meaning	-Has errors in grammar, usage, and mechanics that distract from or interfere with meaning	-Has some minor errors in grammar, usage, and mechanics that do not distract from or interfere with meaning	-Is generally free of distracting errors in grammar, usage, and mechanics
-When appropriate for the task, textual citation is missing or incorrect	-When appropriate for the task, cites textual evidence partially or using incorrect format	-When appropriate for the task, cites textual evidence with some minor errors	-When appropriate for the task, cites textual evidence consistently and accurately
1……..2……..3	4……..5……..6	7……..8	9……..10

Oral Communication

~~1 or~~ Emerging	~~2 or~~ Developing	~~3 or~~ Proficient	~~4 or~~ Advanced
-Line of reasoning is absent, unclear, or difficult to follow	- Line of reasoning can be followed	- Line of reasoning is clear and easy to follow	- Line of reasoning is clear and convincing
· Draws on facts, experience, or research in a minimal way.	· Draws on facts, experience, and/or research inconsistently	· Draws on facts, experiences and research to support a perspective or hypothesis	· Facts, experience and research are synthesized to support a perspective or hypothesis
Demonstrates limited understanding of the topic	Demonstrates an incomplete or uneven understanding of the topic	Demonstrates an understanding of the topic (used data in explanation)	Demonstrate an in-depth understanding of the topic (used data in explanation)
A lack of organization makes it difficult to follow the presenter's ideas and line of reasoning	Inconsistencies in organization and limited use of transitions detract from audience understanding of line of reasoning	· Organization is appropriate to the purpose, audience, and task and reveals the line of reasoning Transitions guide audience understanding	·Organization is appropriate to the purpose and audience and supports the line of reasoning Effectively hooks and sustains audience engagement, while providing a convincing conclusion.
Stumbles over words, interfering with audience understanding	Speaking is fluid with minor lapses of awkward or incorrect language use that detracts from audience understanding	Speaking is fluid and easy to follow	Speaking is consistently fluid and easy to follow
Digital media or visual displays are confusing, extraneous, or distracting	Digital media or visual displays are informative and relevant	Digital media or visual displays are appealing, informative, and support audience engagement and understanding	Digital media or visual displays are polished, informative, and support audience engagement and understanding
· Makes minimal use of presentation skills: lacks control of body posture; does not make eye contact; voice is unclear and/or inaudible; and pace of presentation is too slow or too rushed	· Demonstrates a command of some aspects of presentation skills, including control of body posture and gestures, language fluency, eye contact, clear and audible voice, and appropriate pacing	· Demonstrates a command of presentation skills, including control of body posture and gestures, eye contact, clear and audible voice, and appropriate pacing	· Demonstrates consistent command of presentation skills, including control of body posture and gestures, eye contact, clear and audible voice, and appropriate pacing in a way that keeps the audience engaged
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Summative Assessments

Product: Design and model for the front of a car to reduce injuries in case of a front-end collision. (as demonstrated by the egg-drop activity) Standards Assessed: ● Agency rubric, Collab rubric ● design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision ● Computational Model, Communicate, Scientific theories ● R&D ● Momentum, Newton's 2nd, Models	**Product:** Oral Presentation to explain the design Standards Assessed: ● OC rubric, Collab rubric ● Tech: spreadsheets, use equations, create presentations, District Policy
Test: Multiple Choice Test Standards Assessed: ● Momentum, Newton's 2nd Law, Algebraic thinking ● All Math standards	**Product:** Portfolio of accident reconstruction reports Standards Assessed: ● All ELA standards ● Written Comm rubric, Collab rubric, Agency rubric

At this point I had a CRAZY thought. What if I taught conservation of momentum FIRST, and did the accident reconstructions FIRST? I could then use the students' understanding of how bad car crashes could be as justification for designing better safety procedures. Then I could teach about Impulse and Momentum, as they work on their egg-drop product. I decide to go for it!

My end of the unit summatives will be the MC test, and the oral presentation. I will spread these out over the course of a few days. At the end of one chunk I will have the portfolio, and at the end of another I will have the big egg-drop experiment, which I will treat as a summative for the impulse-momentum theorem.

The Sequence - Chunk #1 - Momentum and its conservation in 1D

Type of Learning Activity	Description	Assessments?
PROJECT ROLL-OUT	Entry document is handed out to groups explaining that they will need to reconstruct a series of accidents to help Napa PD with their workload. The accidents are organized in order of complexity.	Exit ticket for formative assessment. Those who need further explanation will be called aside at the beginning of next class.
Laboratory Experiment	Students look at some simple 1D inelastic collisions with dynamics carts. They are asked to determine the velocities of each cart before and after each collision. They are then asked to make a statement concerning any patterns they see. All carts will be the same mass, and will stick together by aid of velcro.	Written response to lab questions as formative. Those who need it will attend a short workshop about the lab while the rest of the class is watching the video lecture.
Lecture	Follow-up lecture going over the class's results of the lab, and what they should have seen. Basic notes are given on momentum, and the conservation of momentum. The difference between inelastic and elastic collisions are discussed. (Note: elastic collision problems will be written so student do not need to use the kinetic energy equation)	Regular thumbs up/thumbs down formative assessments Note checking pairs (AVID strategy) formative Exit ticket for Point of Confusion Those who need it will attend a workshop on the material while students are working on the Problem of the Day
Video Lecture	Short video lecture explains how to solve conservation of momentum problems by drawing a picture, and then writing out an equation for the conservation of momentum. Also a refresher about unbalanced forces and friction, and how to solve those problems.	

Video Lecture (optional)	How to set-up a spreadsheet to solve these kinds of problems	
Problem of the Day	The first accident reconstruction. Car A is going X mph, when Car B rear-ends it going Y m/s. The two cars lock bumpers and skid to a stop Z ft away.	Answer to the problem is an Exit Ticket. Groups who need help will attend a workshop the next day in class.
Problem set (start in class, finish at home is needed)	Practice unbalanced forces problems, practice simple conservation of momentum problems	Answer to last problem is shared out in class. Students who need additional help will attend a workshop.
Problem of the Day	The second accident reconstruction. Car A is going X mph, when Car B rear-ends it going Y m/s. Car A skids to a stop Z ft away, and Car B skids backwards W ft away.	Answer to the problem is an Exit Ticket. Groups who need help will attend a workshop the next day in class.
Work Time	Class time to do other accident reconstruction problems	
Laboratory Experiment	Elastic Collision lab	Written response to lab questions as formative. Those who need it will be invited to a workshop before the quiz.
		1D Conservation of Momentum Quiz. Free Response. Students who need help are invited to a workshop for reteach, and can then retake the Quiz. (This option for reteach and retake makes this 50% summative and 50% formative)

The Sequence - Chunk #2 - Momentum and its conservation is 2D

Type of Learning Activity	Description	Assessments?
Playing Pool Demo	Video of trick shots from pool, students asked to explain what is going on with each	
Lecture	Basic notes about how 2D conservation works. There is conservation in the x, AND conservation in the y. The sum in each direction must be found.	Regular thumbs up/thumbs down formative assessments Note checking pairs (AVID strategy) formative Exit ticket for Point of Confusion Those who need it will attend a workshop.
Lecture	Basic notes about components of momentum. Break momentum into components using graphical method, and then the sum is found. Then the net momentum is found. (we previously did the graphical method to find net force)	Regular thumbs up/thumbs down formative assessments Note checking pairs (AVID strategy) formative Exit ticket for Point of Confusion Those who need it will attend a workshop.
Video Lecture	Going over how to solve 2D conservation of momentum problems by drawing a picture, breaking momentums into their components, and then setting up an equation and solving.	
Problem of the Day	2D inelastic collision problem	Answer is an exit ticket. Those who need help will attend a workshop.
Work Time	Class time to do other accident reconstruction problems. I will also hold a spreadsheet workshop during this time.	
		2D conservation of momentum Quiz. Free Response. Students who need help are invited to a workshop for reteach, and can then retake the Quiz. (This option for reteach and retake makes this 50% summative and 50% formative)

Summative Due: Portfolio of Accident Reconstruction Reports

The Sequence - Chunk #3 - Impulse-Momentum Theorem

Type of Learning Activity	Description	Assessments?
PSA about seatbelts	Students are asked to describe why seat belts might be helpful in reducing the force felt during a collision	
Project Roll out	Entry document is given which explains that they are being retained to come up with a new cabin design to reduce injuries to occupants during a collision.	Exit ticket for formative assessment. Those who need further explanation will be called aside at the beginning of next class.
Laboratory Experiment	Impulse-Momentum Theorem lab. Velocity before and after being hit are found, and compared to the force that was applied. Conclusion questions have students compare the product of force and time (by area under the curve) and the change in momentum.	
Lecture	Basics of Impulse and momentum are given	Regular thumbs up/thumbs down formative assessments Note checking pairs (AVID strategy) formative Exit ticket for Point of Confusion Those who need it will attend a workshop on the material while students are working on the Problem of the Day
Prototype and Brainstorming	Group work on cabin design as tested by egg-drop	Personal Check-in's
Video Lecture	Video lecture on how to solve impulse-momentum problems	
Problem of the Day	Changing direction problem	Answer is Exit Ticket. Those who need it are invited to a workshop.
Work Time	Work time on cabin design, build, and oral presentation	Exit Ticket for Points of Confusion
Work Time and workshops as needed	Work time on cabin design, build, and oral presentation. I will also hold workshops on whatever the Points of Confusion are.	

Summative Due: Build of Cabin Design, Egg-Drop test, Oral Presentation of Cabin Design, Multiple Choice Test