Topic: Energy Transformations **Title:** Conservation of Energy C.E.R. **Grade Level:** 9th

Standards:
NGSS:
HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
Cross cutting Concepts:

- Systems and System Models: When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
- Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Science and Engineering Practices:

- **Developing and Using Models**
  Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
    - Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5)
- **Constructing Explanations and Designing Solutions**
  Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
    - Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. (HS-PS3-3)

Common Core:
CCSS.ELA-Literacy.RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
CCSS.ELA-Literacy.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
CCSS.ELA-Literacy.WHST.9-10.1.A Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.
CCSS.ELA-Literacy.WHST.9-10.1.B Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.
CCSS.ELA-Literacy.WHST.9-10.1.D Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

CCSS.ELA-Literacy.WHST.9-10.1.E Provide a concluding statement or section that follows from or supports the argument presented.
CCSS.MATH.Content.HSN.QA.2 Define appropriate quantities for the purpose of descriptive modeling.
CCSS.MATH.Content.HSN.VMA.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*).
CCSS.MATH.Content.HSN.VMA.3 (+) Solve problems involving velocity and other quantities that can be represented by vectors.

Timeline:
6- 50 minute periods
Individual days broken down in table below.

Background:
Energy cannot be created or destroyed but it does depend on where you draw the box around the system being observed. Energy can also be measured, but some energies are easier to measure and quantify than others. It is important to be able to keep track of the energies in a system because it allows understanding a system and determining efficiency

Justification:
This unit will allow students to conduct an investigation with the intent of "accounting for" all the energies in a system. My experience says that students need to really think carefully about the transfers of energy to really understand it. The discussions that occur in a group of students while building this investigation, collecting the evidence and presenting/reporting their answers demonstrates a more organized and clear understanding of the content
The lesson will expect students to design an investigation, assess how to properly use mathematical formula for quantifying energy, and present their understanding of content in their own words. They will understand how energy moves in a system, how it is dissipated and how it can be measured.

Objectives:
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- Energy can be transferred within systems and between systems, but never lost.
- Although energy cannot be destroyed, it can be converted to less useful forms.
- Entropy is the degree of randomness and disorder within the system (thermal energy of system).
- The engineering design process is a continuous cycle of predictions, trials and adjustments used to solve complex problems.

Supplies:
Meter sticks, stopwatches (smart phones with slo-mo video also good (other option lab-camera for chromebook)), balances, bouncing balls (e.g. tennis balls, racket balls, rubber bounce balls, wiffle balls), poster paper. (This could also be conducted building comeback cans) Happy and Sad balls for demonstration

5E Lesson sequence:

Engage:	**What is Teacher Doing?**	**What are Students Doing?**
Day 1 Develop ideas about how we can observe and quantify energy in a system. 5-10 min 5-15 min (longer or shorter based on student experience, prior knowledge and questions)	Present Phenomenon: Tennis Ball in Super Slo-Mo Facilitating a recording of question making. (Use Peardeck.com, whiteboards or notebook) Ask students to write various questions about the motion and energy in the video. Discuss with students by eliciting their questions (not to be answered at this time) try to guide the questioning toward the CER question. Presenting the KE and GPE equations (Depending on familiarity) Present calculating velocity and acceleration for a falling object depending on student experience, comfort and abilities. (Remember final velocity of a fallling object can be calculated by multiplying the average velocity during the fall by 2, Final velocity is required for comparing KE at the bottom of the fall with the GPE at the top before falling)	Watching video and Writing questions. Sharing their ideas with partner than with another partner than with class
Explore:	**What is Teacher Doing?**	**What are Students Doing?**
5 min	Present CER question and	Reading and following

	give directions (First Student WS) Present rubric and template (Documents below). Divide class into groups and ask students to start exploring how they would use the materials to conduct an investigation to write their CER. (another location for differentiation based on your experience with students, groups can be hand picked or allow students to choose their own)	directions Asking questions
15 min (time extended or decreased based on time above)	Allow students to work	Working with their partners and supplies to develop a plan to conduct their investigation and discussing how they are going to collect quantitative and qualitative evidence Writing down their plan.
Last 5 min	Ask students to draw and label a picture based explanation of what they are going to do in their investigation and what they expect to see. (This could be an exit slip)	Individually recording a visual representation of their investigation plan
Day 2 Students Conduct investigation, collect evidence/data complete calculations and discuss findings. 30-40 min (timeline will depend on observations from teacher during student investigation students may need more or less guidance either in groups or whole class)	Supervise and facilitate investigations Differentiate as appropriate: (provide procedures formally or through informal interactions and guidance, provide data sheets, assist with use of data in equations) Encourage discussion in groups about how their plan will help groups gather data to address the question with their CER. *(If sensors for motion are*	Finalize investigation plan Collect evidence *(Potentially using smart phones and recording in slow mo or using motion sensors)* Discuss how evidence supports claim. Possible evidence collected: Drop height of ball, time of ball drop, height of call bounce, time of bouncing ball up and down, mass of ball, Possible evidence calculated: Average velocity at various part of ball travel, final

(10 minutes) 10-20 min	*available instruction on their use as appropriate is required and data collection changes based on tools used.)* (*Possible extension at this point is a discussion of Thermal energy equation* $Q=mc\Delta t$) Ask students to summarize their investigations with their group visually (Possible exit ticket)	velocity of drop, GPE before dropping, GPE at top of bounce, KE on first drop, KE on way up from bounce, KE on way down from bounce, percentage error of energy energy calculations. (Students can think about which Measurement of the Balls energy is most accurate (probably GPE) and than consider the error in their investigation) Student collaborate in their groups to visually present their groups investigation.
Explain:	**What is Teacher Doing?**	**What are Students Doing?**
Day 3 Make models of investigation and begin writing CERs 5-20 min 20-30 min	Start class with Happy/Sad ball phenomena. Facilitate discussion about where the energy goes and how it is different between the happy ball and sad ball. If students listen carefully the sad ball makes more noise. *(it is possible that with an IR thermometer a temperature change could be measured in the each ball if they are each "bounced" quickly and repeatedly for around 2 minutes. If Thermal energy equation was taught energy could be calculated based on temp change)* Present Poster model activity. Ask students to discuss in their group how they would draw (minimal words, numbers or equations) a model that explains what they learned in their investigation. *(Groups can vary for this activity combine smaller*	Watch and record questions Ask questions in groups and formulate ideas. Students plan and draw their model for the investigation they conducted and explain/"account" for all of the energy of the "system" or falling ball.

      10-20 min *(Depending on time line and students needs this could be either classwork or HW or some combination)*	*groups into bigger groups, mix up groups or use same groups as during the investigation)* Students work on writing their formal CER	 Either individually, in groups or with partners students work to write their individual CERs as well as they can.
Elaborate:	**What is Teacher Doing?**	**What are Students Doing?**
Day 4 Make Sankey Diagrams Comparing methods of demonstrating their understanding of energy in a system 10-15 min 15-30 min Last 5-10 min HW or class activity **Day 5** Draw an engineered design to theoretically accomplish the increased or decreased dissipation of energy from the	 Instruct students on what a Sankey Diagram is and how they are used Instruct students on how to use Online tool to generate a Sankey Diagram Direct students to make a Sankey Diagram showing the energy in the system of their Bouncing ball Facilitating and Guiding students in groups to make their Sankey Diagrams Ask students to compare their various methods of demonstrating their understanding of energy in a system (CER, Drawn model, Sankey diagram) Request students Watch videos of wine glass breaking with sound Have students watch first 28	 Asking questions Generating Sankey Diagram Students briefly discuss question, and than write their responses. Answering question how does this relate to the bouncing ball? Ask questions

bouncing ball. (Make it bounce better or not at all without changing the ball) 5 min 10 min 25 min 10 min	[seconds of anechoic chamber video] How does this apply to our bouncing ball and the energy transfers that happened in the system of the bouncing ball. Give instructions to students: They are to draw a design for either absorbing the energy of the ball so it doesn't bounce or allow the ball to bounce more effectively without altering the ball. Create new groups. (strategically or not based on class needs and experience with students) Facilitate and guide group work for group designs. Ask groups to share their designs with other groups that tried to accomplish the same goal.	(why the shape of walls, what is up with the floor etc.) Ask Questions follow directions Work in groups to brainstorm ideas Check in with teacher Create drawing of their design Share ideas with other groups who tried to design same idea.
Evaluate:	**What is Teacher Doing?**	**What are Students Doing?**
Day 6 Finalize learning. 15 min Evaluation has been happening throughout this lesson sequence Writing CER	 Ask students to write down their improvements. Ask final question: If energy is being transferred to "less useful" forms why doesn't the room just keep getting louder and or hotter?	 Write how they would improve their design based on discussion with other groups. Students discuss with different partners than submit individual answers.

Sharing ideas Drawing Models Comparing models and understanding Sharing design ideas and Improving design		

Conservation of Energy CER

During this activity you will create a CER to outline the energy transformations associated with the movement of a tennis ball.

Question: Can all of the energies of a system be accounted for?

A tennis ball can have the GPE and the KE measured and calculated but when it is dropped and bounces it does not return to the same height. What happened?

Supplies: Practice Softballs, meter stick(s), stopwatch, balance, other (cell phone with slo-mo, ramp etc)

Your Task: conduct an investigation and write a CER to explain your answer to the question above.

- Your **Claim** must provide a complete answer to the question- Can all of the energies of a system be accounted for? Explain your answer.
- You must include **2** qualitative and **4** quantitative pieces of **Evidence.** Make sure to provide a description of each piece of evidence.
- The **Reasoning** must support your claim in a paragraph format using the evidence provided.

Claims, Evidence and Reasoning Rubric

Modified from: Kevin J. B. Anderson from K. McNeill and J. Krajcik, NSTA

	4	3	2	1	0
Claim – a conclusion that answers the original question **___/8 points**	• Scientifically accurate • Completely answers the question	• Mostly scientifically accurate • Nearly completely answers the question	• Partially scientifically accurate • Partially answers the question	• Is not scientifically accurate • Does not adequately answer the question	• No claim
Evidence – scientific data that supports the claim **___/ 12 points**	• The data/evidence are scientifically appropriate to support the claim. • Multiple pieces of data/evidence are used to support the claim • Proper units are used in data	• The data/evidence are scientifically appropriate to support the claim • One piece of additional data/evidence is needed to be more specific and in depth • Evidence may be repetitive	• The data relate to the claim, but are not entirely scientifically appropriate • More pieces of data/evidence are needed to back up the claim	• There is some evidence provided, but it is not logically linked to the claim or scientifically appropriate • Proper units are not used in data	• No evidence provided
Reasoning – a justification that links the claim and evidence **____/ 12 points**	• Reasoning clearly links evidence to claim showing an in-depth understanding of content • Shows why the data count as evidence by using appropriate scientific principles • There are no spelling, grammar or punctuation issues that hinder meaning.	• Reasoning adequately links claim to evidence showing a general depth of content understanding • Includes related scientific principles, but needs more detail to clarify why this data count as evidence • The paragraph is mostly free of	• Reasoning does not adequately link claim to evidence, or clarify why data count as evidence • Includes related and non-related scientific principles, and shows partial depth of content understanding • The paragraph has several spelling, grammar	• Reasoning is weak and does not make a connection between the evidence and the claim • Scientific understanding is very limited • Spelling and punctuation errors make it challenging to understand the paragraph	• Does not provide reasoning

		spelling, grammar and punctuation errors.	and punctuation errors		
Language and Vocabulary **____/8 points**	• Response clearly and effectively expresses ideas using precise, scientifically appropriate descriptions and vocabulary • Logical progression of ideas (Claim comes first, then evidence and reasoning)	• Response adequately expresses ideas and scientifically appropriate descriptions and vocabulary, but they are more general than specific • Mostly logical progression of ideas	• Response inconsistently and sometimes inappropriately expresses ideas or scientific descriptions and vocabulary • Progression of ideas not entirely logical	• Scientific language and vocabulary are not precise or appropriate • Progression of ideas not logical	• Difficult to understand the response
Overall **____/4 points**	• Focus only on question at hand	• Focus mainly on question at hand, some loosely connected material present	• Focus not consistent on question at hand	• Focus not at all consistent	• No clear focus or organization
Total Points **_____/44**	Additional notes:				

Student CER template

Claim:	
Evidence	**Description**
Reasoning:	

Works Cited

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