2013

Energy Transformations in the Real World

Stephanie Sanders
Trinity University

Dayna Fogle
Trinity University

UNDERSTANDING BY DESIGN

Unit Cover Page

Unit Title: Energy Transformations in the Real World

Grade Level: 11-12

Subject/Topic Area(s): PreAP Physics - Energy

Designed By: Dayna Fogle and Stephanie Sanders

Time Frame: 5 week unit

School District: East Central ISD

School: East Central High School

School Address and Phone: 7173 FM 1628 San Antonio, TX 78263 phone: (210) 649-2951

Brief Summary of Unit (Including curricular context and unit goals):

This energy unit is intended as part three of a three part series where students use launchers to explore how scientists combine theory and measured data to build and use predictive models. The launchers will be used during projectiles, forces, and work/energy and students will measure and use data adjusted theoretical models to endeavor to complete two hands-on performance tasks. Historically, our students have struggled to understand why "physics breaks" in the lab, and we intend to use these launchers throughout our Newtonian mechanics units to open an ongoing dialogue about how modeling is used to bridge the gap between theory and real world behavior. The three parts work as follows:

1. In the projectile unit, students will work in groups to build a spring loaded launcher and use real time technology to form a predictive equation relating exit velocity to spring displacement. They will then use this model to launch their ball into a cup from a horizontal position and an angled position as the performance task in this unit.
2. In the forces unit, students will perform a laboratory analysis on their spring(s) to observe the relationship between force and spring displacement for the launcher spring and to determine where Hooke's Law is an appropriate model

for finding the spring constant. Students will complete a formal lab write-up as the performance task in this unit.

3. In the energy unit, students will use conservation of energy to model their launcher's performance for a vertical orientation, measure the launcher's performance, analyze the error and develop a predictive model that will allow them to accurately launch a ball to a given height (within a tolerance).

In this unit (part 3 from above), students will use the experimentally determined spring constant value from part two, and use it to calculate the maximum height achieved by their launcher for various spring deformations using the previously determined spring constant and energy transformations (elastic to kinetic to gravitational potential) in their systems. Students will then spend several days testing the actual performance of the launchers, calculating the error in the theoretical model, explaining these errors, and then creating a predictive model that accounts for these errors to prepare for the performance task day when they will attempt to launch their ball to a teacher specified height.

To accomplish the performance task, students will need to develop the ability to use the equations for kinetic, elastic potential, and gravitational potential energy to calculate variables, apply conservation of energy to a system, and explain what forces perform non-conservative work on the system to explain a loss of mechanical energy from the system. Thus, the unit introduces conservation concepts, work, forms of energy, mechanical energy equations, conservation of mechanical energy calculations, and conservation of total energy in situations with non-mechanical work. Further, students will be solidifying skills in cooperative learning, graphical analysis, reporting scientific information, use of real time technology and laboratory skills.

The task students are asked to complete has been purposefully designed to be extensive and part of an ongoing project. Our students have raised objections to shorter term projects that require building investment and are used for a short amount of time. We feel that this longer term project will enhance student buy-in while allowing them to explore how to do science. We hope that by allowing our students sufficient time to confront and overcome the challenges associated with developing predictive models and then apply these models to accomplish a task, we will help them to see science as an evolving discipline full of area for exploration and innovation.

Stage 1 – Desired Results

<table>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="6">Physics TEKS
P.2H: Make measurements with accuracy and precision and record data using scientific notation and International System (SI) units.
P.2I: Identify and quantify causes and effects of uncertainties in measured data.
P.2J: Organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs.
P.2K: Communicate valid conclusions supported by the data through various methods such as lab reports, labeled drawings, ~~graphic organizers, journals, summaries,~~ oral reports~~, and technology-based reports~~.
P.2L: Express and manipulate relationships among physical variables quantitatively, including the use of graphs, charts, and equations.
P.6A: Investigate and calculate quantities using the work-energy theorem in various situations.
P.6B: Investigate examples of kinetic and potential energy and their transformations.
P.6C: Calculate the mechanical energy of, power generated within, ~~impulse applied to, and momentum~~ of a physical system
P.6D: Demonstrate and apply the laws of conservation of energy ~~and conservation of momentum~~ in one dimension.
P.6E: Describe how the macroscopic properties of a thermodynamic system such as temperature, specific heat, and pressure are related to the molecular level of matter, including kinetic or potential energy of atoms.
P.6F: Contrast and give examples of different processes of thermal energy transfer, including conduction, convection,</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will independently use their learning to…
model, measure, and analyze the energy behavior in a launcher system using conservation of energy, the concept of heat generated by work done by non-conservative forces, and use their energy understandings to use a spring loaded launcher to achieve a specified height.

Ultimately the student will know that changes occur within a physical system and apply the laws of conservation of energy.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>Understandings
Students will understand that….
The total mass and energy of the universe is a conserved (constant) quantity that can neither be created nor destroyed, only transformed.

Work is the transfer of energy between two objects accomplished by applying a force over a displacement.

Energy is classified into two broad categories stored energy (potential) or energy due to motion (kinetic).

Energy readily transforms from one form to another, but these transformations are not always reversible.

Our perception of hot or cold is related to differences in temperature (average kinetic energy) but also to the capacity of substances to soak up energy in rotations, internal vibrations and bond stretching (specific heat capacity).

Heat is the transfer of thermal energy (called heat) using the modes of conduction, convection and radiation.

Internal energy is the total molecular kinetic and potential energy within an object whose change will cause an increase in temperature (kinetic energy) or a phase change (potential energy).</td><td>Essential Questions

Why do things have energy?

How can energy be transferred from one material to another?

What happens to a material when it receives energy?

What happens to the energy in a system — where does this energy come from, how is it changed within the system, and where does it ultimately go?

How does the flow of energy affect the materials in the system?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Knowledge
Students will know…
• The relationship between mass and energy shown in E=mc^2, that energy and mass are the same.
• The Law of Conservation of Energy and Mass is a significant property in that energy/mass cannot be created (made) nor destroyed (consumed).
• Energy can be transferred from one object or system to another through various methods.</td><td>Skills
Students will be able to…
• Classify various forms of energy as mechanical or non-mechanical
• Calculate work done by or on a system using $W = Fd$
• Calculate the rate of energy transfer (work) using $P = \frac{W}{t}$ or $P = \frac{\Delta E}{t}$
• Calculate Kinetic Energy using $KE = \frac{1}{2}mv^2$
• Calculate Gravitational Potential Energy using $U_g = mgh$</td></tr>
</table>

and radiation. **P.6G:** Analyze and explain everyday examples that illustrate the laws of thermodynamics, including the law of conservation of energy and the law of entropy.	• Electromagnetic energy (radiant/light energy) is carried by electromagnetic waves. • Thermal energy represents the total random kinetic energy of molecules of a substance versus Internal energy is the total molecular kinetic and potential energy within an object. • Chemical energy is the energy stored in the bonding of atoms and molecules (movement of electrons) whereas nuclear energy is associated with nucleus (protons/neutrons). • Although mechanical energy is transformed into heat energy, the random nature of heat energy makes it impossible for it to fully transfer back into mechanical energy or another organized form of energy. • Organized forms of energy are more useful than disorganized forms (heat energy). • Work is the result of a force applied in a parallel direction to its displacement and transfers energy to an object. • Work resulting from non-conservative or path-dependent forces transforms some system energy into non-mechanical energy reducing the work potential of the system. • Efficiency is a relationship between work output (what machine/system is able to do with energy inputted) and work input (what energy is applied to a machine/system) of a system (Work Output/ Work Input * 100 = %Efficiency) and it will never reach or exceed 100%. • Power is a quantity that tells us how quickly energy is transferred to or away from an object. • The kinetic energy of an object is directly proportional to mass and directly squared proportional to the speed of the object. • Potential energy comes from the influence of gravity, elastic forces or electric forces and is determined from its position. • Gravitational potential energy of an object increases with the weight of an object (mg) and with its height (h) above a pre-defined point. • Elastic potential energy relates to an object's deformation from equilibrium and is directly proportional to the object's ability to bounce back (called the spring constant) and directly squared proportional to the displacement from equilibrium. • Momentum of an object is a property of	• Calculate Elastic Potential Energy $U_e = \frac{1}{2}kx^2$ • Calculate the energy resulting from work done on an object as $W = \Delta KE$ • Choose an appropriate set of the above equations to solve for energy transformations in essentially frictionless systems where mechanical energy is conserved - rollercoasters, pendulums, mass/spring systems using $\Delta E_{system} = 0$ • Choose an appropriate set of the set of the above equations to solve for energy transformations in systems where mechanical energy is not conserved (systems with friction) - PreAP Only

	its motion that can be calculated from its mass and its velocity (P = mv), and only forces can change the momentum of an object. • Law of Conservation of Momentum (like energy and mass) is a conserved quantity, and describe how this property makes it a useful tool in problem solving. • Impulse is the relationship between the force acting on an object and the change it produces in the object's momentum ($J = \Delta P = F_{avg} \cdot \Delta t$). • Collision forces will be reduced when the barriers are flexible (increasing Δt decreases F_{avg}).	

Stage 2 – Evidence

CODE (M or T)	**Evaluative Criteria** (for rubric)	
T T M T M T M	See rubric	Performance Task(s) *Students will demonstrate meaning-making and transfer by…* Major: Produce a body of evidence that allows successful prediction of the performance of a self-made energy system by predicting the height a spring loaded launcher will achieve. The body of evidence will consist of a binder or electronic resource containing: • A detailed description, including sketches or pictures, of the final design – continued from previous units. • Theoretical calculations for height achieved, calculated using energy conversions between elastic, kinetic, and potential energy. • Measurements for actual results achieved • A comparison (percent error), between actual results (using a motion detector for velocity) and achieved results with an explanation for error. • A final prediction for height and reported results for real time test. -- Other Evidence (e.g., formative) • Work Quiz – Day 3 • Video recording or drawing demonstrating at least 4 energy transformations. – Day 4 • Project Checkpoint 1 – Launcher Working • Online Work-Energy Theorem Quiz – Day 9 • Drawn and qualitatively graphed skate park system with 3 hills – Day 10 • 3 Week Test – Calculating work, power, kinetic energy, gravitational potential energy, and elastic potential energy. – Multiple choice with free response essay re: energy types – Day 11

T M M T T T T T		• Conservation of Mechanical Energy Whiteboard Quiz – Day 12 • Project Checkpoint 2: Theoretical Calculations Pre-lab and Theoretical Energy Calculations Checklist – day 13/14 • Non-conservative Forces Roller Coaster Lab – Prelab – day 14 • Non-conservative Forces Roller Coaster Lab – Postlab – day 15 • Project Checkpoint 3: Lab 2: Measurement of Actual Results - pre and post – days 18/19 • Conservation of Energy with Non-Conservative Work Quiz – Day 21 • Project Checkpoint 4: Error Analysis of Launcher – Day 23 • Power Quiz – Day 23 • 6 Week Test – Energy conversions (Free response) and 2 week test material (MC)

Physics Launchers: A Study in Theory vs. Actual Physics in Action – Teacher Document

Background: We intend for our students to build and use simple spring loaded ball launchers and have written this performance task to be a three part series. Students will use launchers to explore how scientists combine theory and measured data to build and use predictive models. The launchers will be used during projectiles, forces, and work/energy and students will measure and use data adjusted theoretical models to endeavor to complete two hands-on performance tasks. Historically, our students have struggled to understand why "physics breaks" in the lab, and we intend to use these launchers throughout our Newtonian mechanics units to open an ongoing dialogue about how modeling is used to bridge the gap between theory and real world behavior. The three parts work as follows:

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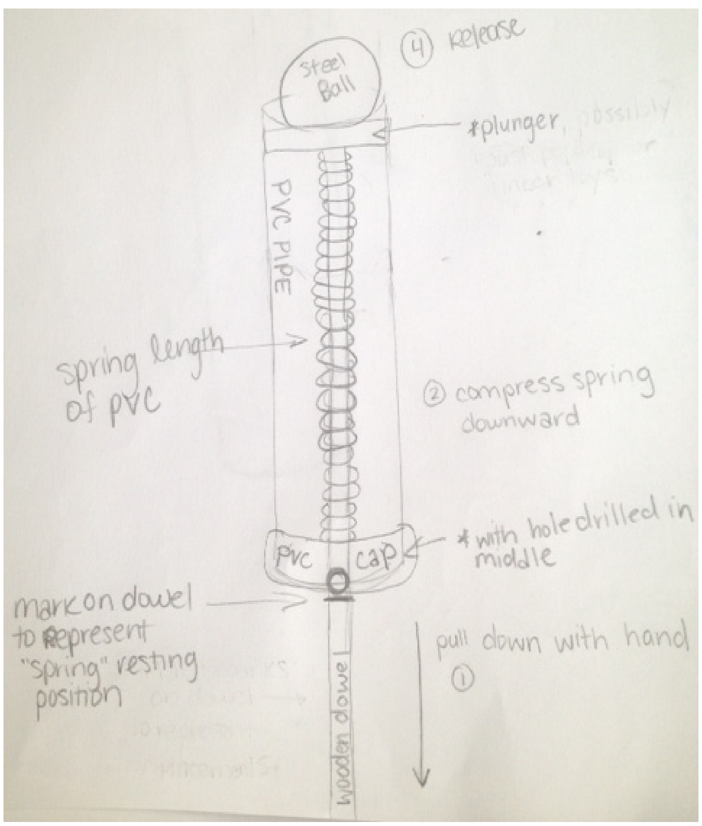
3. In the energy unit, students will use conservation of energy to model their launcher's performance for a vertical orientation, measure the launcher's performance, analyze the error and develop a predictive model that will allow them to accurately launch a ball to a given height (within a tolerance).

Goal: Engage students in doing real physics work and by allowing them to do real science, help them to see science as an evolving discipline full of area for exploration and innovation.

***The Launcher*:** Due to limited financial resources, our goal is to build simple physics launchers that rely on compression or extension of a spring to provide the energy source. We envision our launchers looking like this:



Anticipated materials include:
1. A spring capable of launching between 1 and 2 meters
2. A plunger – currently investigating the use of tinker toys versus push-up popsicles (visual here http://www.gerritysdelivers.com/7255400260.html)
3. 1 inch PVC pipe cut to size
4. A PVC Cap with a drilled hole in it
5. Steel ball bearings or plastic large marbles.

Anticipated cost ($3-$5 per launcher)

The Plan: We plan to build the launchers this summer and then to video record a step-by-step building process for other teachers/students. In addition, we plan to provide flipped classroom videos as homework for students to use when designing, building, altering, and calibrating their launchers.

Alternates:
1. A different kind of launcher: http://youtu.be/YPext4tmuW8
2. Prebuilt launchers: CPO's version: http://store.schoolspecialty.com/OA_HTML/ibeCCtpItmDspRte.jsp?minisite=10020&item=47454

Resources (Resources included in this unit are marked with a *):

1. Physics Launchers: A Study in Theory vs. Actual Physics in Action – Teacher Document - *****
2. Phase 1: Projectiles
    a. Student introduction video
    b. Projectiles Assignment Sheet for students
    c. Rubric
3. Phase 2: Forces
    a. Flipped Classroom video reviewing Hooke's Law and helping with lab design
    b. Hooke's Law Student Designed Lab: k Making all the Difference, One Spring at a Time… **- ***
    c. Hooke's Law Student Designed Rubric: k Making all the Difference, One Spring at a Time… **- ***
4. Phase 3: Energy
    a. Launcher Liveliness: How Your Launcher Uses Energy – Student Introduction Document - *
    b. Build Day 3 – Launcher Liveliness: Energy Revisions Checklist - *
    c. Launcher Liveliness: Theoretical Energy Calculation Checklist - *
    d. How Your Launcher Uses Energy (Resource/Data Sheet) - *
    e. How Your Launcher Uses Energy (Instructions) - *
    f. Theoretical Calculations Flipped Classroom Video
    g. Measurement Lab Flipped Classroom Pre and Post Lab Videos

Part 2: Forces Unit - Hooke’s Law and Springs

k Making all the Difference, One Spring at a Time…
Hooke's Law - Part A

Introduction:

We built spring loaded launchers when we were learning about projectile motion and used them to launch a ball with a certain velocity horizontal to make it into a cup a defined distance away. **In this laboratory challenge, your goal is to find the spring constant (k) of the spring used in your launcher.** Listed below are the materials that will be available to you in order to answer this question. Your task is to design a strategy or experiment for answering this question. **The formal, "typed" design will be due the day before the scheduled lab in your group's binder/bradded folder.** Then, you will follow your instructions in order to test your spring from your spring loaded launcher.

**Be sure to design your experiment in a way that tests YOUR spring (so if your launcher uses "extension", extend the spring/ if your launcher uses "compression" of the spring, compress your spring).*

Materials available:

- A set of masses which totals 1 kg
- Graph paper
- Spring from launcher
- C-clamp
- Calculator
- Pendulum Clamp
- Mass hanger
- Ruler/ meter stick
- Aluminum pole in table
- Ring stand

Background/Problem:

Hooke's Law describes the relationship between the force applied to a spring and its elongation (stretch). That is, if a force stretches a spring, the elongation is directly proportional to the force applied. "k" is a spring constant, which is based on the "stiffness" of an elastic material. If a spring is difficult to compress or extend, if will have a large spring constant and be able to store more energy.

$$F = -kx$$

F = force in Newtons (N)
k = spring constant in Newtons/meter (N/m)
x = elongation in meters (m)

Post Lab/Extension:

How far (distance) *will you need to compress or extend (depending on type of launcher you built) your spring in order to launch a ball causing a force of 2N on the ball? Think about how you can use your data found in your experiment to answer this question.*

Your lab report will include:

Lab Information: Lab title, name, group members, date(s) of performing experiment.

I. Purpose: A brief statement of the purpose or objective of the experiment.
II. Materials: You should include a list of all lab equipment you need
III. Procedures: Write your procedures so that anyone can easily duplicate your data with a set of instructions.
You will use numbered instructions on lab day but formally write them in paragraph form with your lab report
IV. Data and Observations
*Run at least 2 trials
V. Graphs: (if applicable): Always create representations of your data in graphical form and include a brief description of what you are trying to show
VI. Calculations: Carefully show the steps for any mathematical calculations
VIII. Conclusions: Recall that you performed the experiment with a specific purpose in mind, reflect on the purpose, state results, think of ways to improve the experiment.

Resources to assist you in designing:
http://www.4physics.com/phy_demo/HookesLaw/HookesLawLab.html

k Making All the Difference, One Spring at a Time

Topic	Exceeds Expectations	Meets Expectations	Approaching Expectations	Does not Meet Expectations	
	5 pt	**4 pt**	**3 pt**	**Up to 2 pt**	
Title/ Purpose	Meets expectation and makes connection to pre-lab video/ information.	Names included, date, period, Title “Purpose of experiment” is stated in own words 1-2 sentences, clearly presenting a rational purpose of the lab.	Names included, date, period, Title “Purpose of experiment” is stated in own words 1-2 sentences, but does not present a rational purpose to the lab.	Names included, date, period, Title “Purpose of experiment” is missing or copied directly from info page.	**/5**
Diagram/ Schematic **X2**	Meets expectations AND includes labels of how the apparatus should work (ex: directions things should move)	A clear picture/blueprint is included of what the design of the apparatus students put together, including labels of equipment pieces.	A neat picture/sketch without labels is included of what the design of the apparatus students put together. OR A messy sketch WITH labels is included.	A messy sketch or is included of what the design of the apparatus students put together AND does not include labels	**/10**
Materials	List of materials used includes all necessary equipment			List is missing items	**/5**
Procedures (For Lab use) **X2**	Meets expectations but more than enough pictures and/or drawings are included in procedures to clarify.	Numbered procedures are included and are well written and easy to follow. A teenager or adult could reproduce the experiment. Pictures and/or drawings are included in procedure to clarify.	Procedures are well written but are too vague making it difficult to follow. A teenager or adult could reproduce the experiment with difficulty. No pictures are included to help clarify.	Procedures are included but are missing steps or are incomplete. A teenager or adult could not reproduce the experiment.	**/10**
Procedures (Lab Report) **X2**	Paragraph format is included in lab report and is well written and easy to follow.			Paragraph format is not included in the lab report.	**/10**
Data: Data Tables/ Observations **X3**	Meets expectations but includes observations to help communicate the data.	Title and labels included on each data table, at least 2 trials are displayed as well as averages, Units and Variables are included. All data is reported.	Title and labels included on each data table, only one trial is evident. Units and Variables are included. OR Two trials are evident BUT Units and Variables are missing.	Title and labels included on each data table, only one trial is evident. Units and Variables are missing.	**/15**

Data Analysis: Graphs **X3**	Meets expectations but includes a paragraph explanation of what the best fit line represents and what k is, is included under the graph.	Title effectively represents what is being shown, graph is large and covers at least 50% of paper, labeled axes with units, clearly identified data points, best fit line on most linear part of the graph, slope is clearly labeled, a sentence explanation of what the best fit line represents, is included under the graph.	Title effectively represents what is being shown, graph is large and covers at least 50% of paper, labeled axes with units, clearly identified data points, best fit line on most linear part of the graph, and slope is clearly labeled. (No explanation included)	Title effectively represents what is being shown, graph is large and covers at least 50% of paper But: Axes may not be labeled And/or best fit line is missing or not drawn correctly and/or slope is not clearly labeled or missing	**/15**
Error Analysis **X2**	Meets expectations and shows deep understanding of meaning of percent error through a discussion of what variables could possibly affect the results.	Student calculates percent error between slope-derived "k" and "k" for each point. Calculation is neat and clearly presented. Discusses meaning of percent error with respect to range for correlation.	Student calculates percent error between slope-derived "k" and "k" for each point. Calculation is neat and clearly presented. Discussion is present but is merely a list of facts.	Student calculates percent error between slope-derived "k" and "k" for each point. Calculation is present. Discussion is missing.	**/10**
Conclusion **X2**	Meets expectations but is thoroughly written with multiple paragraphs. Shows deep reflection on the experiment design.	Written in paragraph format (at least 4 sentences) that answers the purpose of the lab, states numerical results with correct units including percent error, relationship between variables in Hooke's Law is noted, statement about the design of the lab and how it could be improved or modified.	Written in paragraph format (at least 4 sentences) that relates back to the purpose of the lab, states numerical results with correct units including percent error, relationship between variables in Hooke's Law is noted.	Written in paragraph format that restates the purpose of the lab, states numerical results, but shows no reflection on the results.	**/10**
Post Lab/Extension	Meets expectations but discussion shows deeper thinking and connections to other topics in physics previously or not yet discussed.	Results are communicated through the use of theoretical calculations, graphs from Vernier force probe, and a discussion of what the graphs are showing. Percent error calculation is present.	Results are communicated through the use of theoretical calculations, graphs from Vernier force probe. Discussion of what the graphs are showing OR percent error calculation is missing.	Results are communicated through the use of theoretical calculations, graphs from Vernier force probe. Discussion AND percent error is not included.	**/5**
Total					

Part 3: Energy Unit - Conservation of Energy and Non-Conservative Work

Launcher Liveliness: How Your Launcher Uses Energy

Launchers Part 3

Our launchers are returning to the classroom to help us better understand energy conversions. You and your team will need to dust off your launcher, do a "flight check," and repair/alter/revamp as needed

to have it in working order by no later than __________________.

Final launch will be ________________________.

As per normal, stock supplies (glue guns, glue sticks, wood glue, and various tools) will be available in class for use during lunch, before school and after school.

 Launch your ball vertically to within 0.1 m of the target line

 to the 

Step	Class Time	Resources to Help	Graded On:
1. Build Day 3: Repair/alter/revamp your launcher and revise your description	T 1/28/2014	Stock supplies Build Day 3 – Launcher Liveliness: Energy Revisions Checklist	2/11/2014
2. Theoretical Energy Calculations	M 2/10/2014	Launcher Liveliness: Theoretical Energy Calculation Checklist and your notes	2/14/2014
3. Lab 2: Measure Actual Results	T 2/18/2014	Launcher Liveliness: How Your Launcher Uses Energy (Instructions and Resource/ Data Sheet)	2/21/2014
4. Find error between theory and reality (Steps 2 and 3) Find your Prediction method	W 2/19/2014	Launcher Liveliness: How Your Launcher Uses Energy (Resource/ Data Sheet)	2/25/2014
5. Launch to the Target	T 2/25/2014	Height for launch given on M 2/24/2014	T 2/25/2014

See the Launcher Liveliness Rubric for more information about grading.

Please remember: Exceeds Expectations = 100 (105 but capped at 100), Meets Expectations = 84, Approaching = 63.

10 point bonus (maximum) for performance.

Launcher Liveliness Rubric:

The following rubric will be used to assess your "Energy is Energy" project. Use the rubric below to help guide you. Projects are due___________________.

Topic	Exceeds Expectations	Meets Expectations	Approaching Expectations	Does not Meet Expectations	Total Points
	Up to 15 pt	**Up to 12 pt**	**Up to 9 pt**	**Up to 5 pt**	
Launcher	Launcher is exceptionally built, complete on time or early, and converts elastic potential energy into kinetic energy and then into gravitational potential energy.	Launcher is well built, complete on time or early, and converts elastic potential energy into kinetic energy and then into gravitational potential energy.	Launcher is built, complete on time, but does not consistently convert elastic potential energy into kinetic energy and then into gravitational potential energy.	Launcher does not successfully convert elastic potential energy into kinetic energy and then into gravitational potential energy. OR Not complete on time.	
Launcher Description	A procedure for building the launcher is included and it is well written and easy to follow. A teenager or adult could reproduce the launcher. Pictures and/or drawings are included for each step in procedure to clarify.	A procedure for building the launcher is included and it is well written and easy to follow. A teenager or adult could reproduce the launcher. Pictures and/or drawings are included in procedure to clarify.	A procedure for building the launcher is included but missing a few details that make it vague. A teenager or adult could reproduce the launcher with help. A picture and/or drawing of the finished device and materials are in procedures to clarify.	A procedure for building the launcher is included but very difficult to follow or incomplete. A teenager or adult would have a hard time reproducing the launcher. No pictures and/or drawings are included in procedure to clarify.	
Theoretical Calculations (All Ue)	Theoretical Calculations Checklist is complete. Students have justified the inclusion or removal of potential energy inside the launcher.	Theoretical Calculations Checklist is complete. Theoretical predictions are complete with all variables calculated shown for every energy state (elastic, kinetic, and potential). All work is shown with givens, unknown, equations, math, and solution. Units are present throughout calculations and solutions.	Theoretical Calculations Checklist is incomplete in 1 of the following ways: • One variable is missing for each energy state • Work is incomplete or insufficient • Units are consistently missing on throughout.	Theoretical Calculations Checklist is incomplete in more than 1 of the following ways: • One variable is missing for each energy state • Work is incomplete or insufficient • Units are consistently missing on throughout.	
Theoretical Calculations (All KE)	Theoretical Calculations Checklist is complete. Students have justified the inclusion or removal of potential energy inside the launcher.	Theoretical Calculations Checklist is complete. Theoretical predictions are complete with all variables calculated shown for every energy state (elastic, kinetic, and potential). All work is shown with givens, unknown, equations, math, and solution. Units are present throughout calculations and solutions.	Theoretical Calculations Checklist is incomplete in 1 of the following ways: • One variable is missing for each energy state • Work is incomplete or insufficient • Units are consistently missing on throughout.	Theoretical Calculations Checklist is incomplete in more than 1 of the following ways: • One variable is missing for each energy state • Work is incomplete or insufficient • Units are consistently missing on throughout.	

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Actual Result Measurements	How Your Launcher Uses Energy (Resource/Data Sheet)is complete Explanations for errors are reasonable and show an above high school level of understanding.	How Your Launcher Uses Energy (Resource/Data Sheet) is complete Actual results are recorded in a neat data table with appropriate units. Error calculations comparing theoretical and actual results are complete with work shown for velocity and height predictions. Explanations for errors are reasonable and show a high school level of understanding.	How Your Launcher Uses Energy (Resource/Data Sheet) is incomplete in 1 of the following ways: • One measured variable is missing from reported results • Error calculations work is incomplete or insufficient. • Error calculations are incorrect. • Error explanations are below high school level.	How Your Launcher Uses Energy (Resource/Data Sheet) is incomplete in more than 1 of the following ways: • One measured variable is missing from reported results • Error calculations work is incomplete or insufficient. • Error calculations are incorrect. • Error explanations are below high school level.	
Final Prediction	Final prediction shows that students made a scientifically reasonable attempt to reconcile differences between theoretical and actual results by considering percent error. Graphs are used.	Final prediction shows that students made an attempt to reconcile differences between theoretical and actual results by considering percent error. Graphs are used.	Final prediction shows some evidence of thought but is based solely on actual OR theoretical results OR Does not include graphs.	Final prediction shows little/no evidence of thought.	
	10 pts				
Performance Bonus	Ball stops <0.1 m from target line				

Build Day 3- Launcher Liveliness: Energy Revisions Checklist

Launchers Part 3

*Please use this checklist to ensure that your launcher is ready to participate in the Part 3 energy challenge. You launcher must be in **fully working order by no later than 2/11/2014** at the beginning of class.*

Launcher Functionality Check (Up to 10 points):

- I have a working launcher
- My launcher relies only on the spring to provide the force to the ball.
- When released, my launcher reliably launches the ball.
- My launcher launches the ball straight out of the barrel with little/no spin.
- My launcher is able to launch a ball vertically upward.

Launcher calibration for k and x(Up to 5 points):

- I have clearly marked my launcher to show how much the spring is stretched or compressed in small increments (1 mm).
- I know how spring compression/extension relates to Force applied (Hooke's Law)
- I have visually indicated where the spring obeys Hooke's Law (linear portion of Hooke's Law graph)

Launcher Description Document (Up to1 5 points):

- I have a Launcher Design Document
- I have updated my Launcher Design Document to account for all functionality changes made since the last revision.
- I have updated my Launcher Design Document to explain the markings for compression/extension
- I have updated my Launcher Design Document to show where the spring obeys Hooke's Law.
- I have included visuals (drawings or pictures) as appropriate to aid a reader's ability to reproduce my launcher.

Launcher Liveliness: Theoretical Energy Calculation Checklist

Launchers Part 3

Please use this checklist to ensure that your Theoretical Energy Calculations are complete for the Part 3 energy challenge. You calculations must be complete and in my hands by no later than 2/14/2014 at the beginning of class.

Number of points chosen (Up to 3 points):

- I have done energy conversion calculations following the checklists below for at least 4 points.
- The 4 points I have chosen are within the linear region of my length versus spring force graph ensuring that my spring is obeying Hooke's Law for the region I am calculating.
- I have indicated whether I will account for the gravitational potential energy change inside my launcher and justified my choice.
- My 4 points span the entire linear region for my spring.
  - 1 point is at the start of the linear region.
  - 1 point is at the end of the linear region.
  - Remaining 2 points are equally space between the two points above.

*For **each** data point -minimum of 4 data points (Up to 7.5 rubric points per data point):*

All Elastic Potential Energy (Up to 2.5 points):

- I have labeled these calculations Theoretical Calculations: All EPE, Spring Compression ____ m
- I am doing these calculations at the point where the spring is either fully stretched or fully compressed (depending on whether I stretch or compress my spring prior to launch).
- I have written my givens.
- I am using my spring constant that I found in my Spring Constant Lab during the forces unit.
- I have shown the appropriate equation for Elastic Potential Energy.
- I have solved for Elastic Potential Energy.
- My solution has appropriate units.
- My work is completely written out, easy to follow, and neat.

Mostly Kinetic Energy (Nozzle) (Up to 2.5 points):

- I have labeled these calculations Theoretical Calculations: All Kinetic Energy, Spring Compression ____ m
- I am doing these calculations at the point where the spring is at equilibrium (should be the nozzle of my launcher)
- I have written my givens.
- I am assuming conservation of energy with no nonconservative forces.
- I have shown the appropriate equation to solve for Kinetic Energy
- I have shown the appropriate equation to solve for velocity given Kinetic Energy from the previous step.
- I have solved for Kinetic Energy
- If appropriate, I have solved for Gravitational Potential Energy
- I have solved for the ball's velocity
- My solutions have appropriate units.
- My work is completely written out, easy to follow, and neat.

All Gravitational Potential Energy (Up to 2.5 points):

- I have labeled these calculations Theoretical Calculations: All Gravitational Potential Energy, Spring Compression ____ m
- I am doing these calculations at the point where the ball is at its highest point
- I have written my givens.
- I am assuming conservation of energy with no nonconservative forces.
- I have shown the appropriate equation to solve for Gravitational Potential Energy
- I have shown the appropriate equation to solve for height given Gravitational Potential Energy from the previous step.
- I have solved for Gravitational Potential Energy
- I have solved for the ball's maximum height
- My solutions have appropriate units.
- My work is completely written out, easy to follow, and neat.

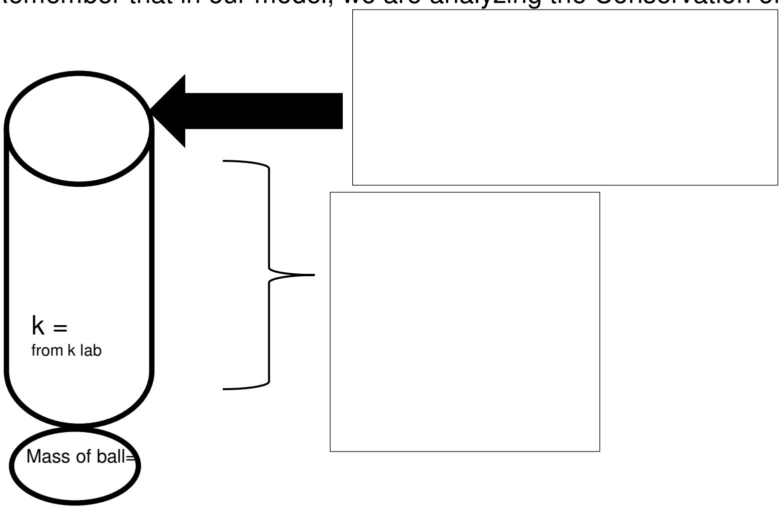
Launcher Liveliness: How Your Launcher Uses Energy (Resource/ Data Sheet)

Launchers Part 3

Look through the binder your group has created thus far. Record the data you have collected from previous labs in the appropriate tables in order to use as a resource sheet. This is equivalent to you listing your givens in order to predict how you will meet the final goal of hitting a specified height.

Your goal is NOT to calibrate your launcher with a "test and mark" strategy. You are to calculate how much work you are doing on the spring, converting your kinetic energy into elastic potential energy, and use this value to calculate for a THEORETICAL height that the ball will reach.

Remember that in our model, we are analyzing the Conservation of Energy through its transformations.



Projectile:
$\Delta x = v_i \Delta t + \frac{1}{2} a (\Delta t)^2$
Spring constant:
$F = -kx$
Kinetic Energy:
$KE = \frac{1}{2} m v^2$
Gravitational Potential Energy:
$U_G = mgh$
Elastic Potential Energy (spring):

Theoretical Calculations:

See checklist for instructions on how your group will calculate for all of the given variables. Each member is required to turn in at least one FULLY worked solution. (I should see different handwriting!)

Theoretical Calculations Data Table					
k=	$Mass_{ball}$=				
x	U_E	**v**	**KE**	**h**	U_G

Graphs:

Actual Data Collected:

Following the launch instruction page, launch your ball from each "x value" in your theoretical calculations. Using data from graphs record your values in the data table.

Experimental Data Table									
k=	$Mass_{ball}$=								
x	**U_E**	**v**			**KE**	**h**			**U_G**
	$U_E=\frac{1}{2}kx^2$	**Trial 1**	**Trial 2**	**Avg.**	KE = $\frac{1}{2}mv^2$	**Trial 1**	**Trial 2**	**Avg**	U_G=mgh

Error Analysis:

$$\%\ error = \frac{Theoretical - Experimental}{Theoretical}\ x\ 100$$

Velocity of ball as it left the launcher
$v_{theoretical}$ & $v_{experimental}$

Your individual Calculation:

X	v_{theor}	v_{exp}	% error

Height ball reaches
$h_{theoretical}$ & $h_{experimental}$

Your Individual
Calculation:

X	h_{theor}	h_{exp}	% error

Percent Efficiency:

$$\%\, efficiency = \frac{Work\ Output}{Work\ Input} = \frac{U_G}{U_E}$$

Your Individual Calculation:

X	U_g	U_E	% efficiency

Discussion of results:

Please use this checklist to ensure that your error analysis calculations are completed and portray your understanding of how your theoretical calculations compare to your experimental results in the Part 3 energy challenge.

Error Analysis Check (15 points total):

Graphs from Data Collection (1 point):

- I have electronically saved all of my distance versus time graphs (at least 8, 2 trials for each stretch/compression distances) and a velocity versus time graphs (at least 8, 2 trials for each stretch/compression distances) that clearly define a maximum velocity and a vertical displacement of the projectile during my predicted launch.

Distance versus time data table (2 points)

- I have filled out the data table provided showing both trials of each stretch/compression distances.
  - I have inserted the stretch/compression distance (x)
  - I have looked at the graph and subtracted d_{final}-$d_{initial}$ or maximum distance minus minimum distance to get experimental height value
  - I have inserted my theoretical heights and experimental heights into the error analysis data table with units.

Velocity versus time data table (2 points)

- I have filled out the data table provided showing both trials of each stretch/compression distances.
  - I have inserted the stretch/compression distance (x)
  - I have looked at the graph and used the point of maximum velocity (assuming that the projectile is the fastest at the moment it is launched)
  - I have inserted my theoretical velocities and experimental velocities into the error analysis data table with units.

Error Analysis Calculation (5 points)

- I have included one completely worked out calculation of finding percent error that is easy to follow and neat for both velocity and height.
- I have written my givens.
- I have shown the appropriate equation for solving for percent error.
- I have calculated all percent errors and inserted them into the data table provided.
- My solutions have appropriate units.

Percent Efficiency Calculation (5 points)

- I have included one completely worked out calculation of finding percent efficiency that is easy to follow and neat.
- I have written my givens.
- I have shown the appropriate equation for solving for percent efficiency.
- I have calculated all percent efficiencies and inserted them into the data table provided.
- My solutions have appropriate units.

Launcher Liveliness: How Your Launcher Uses Energy

Instructions for Collecting your Data

We will collect experimental data through the use of motion detectors that will record the movement of the ball in the vertical direction.

1. Record your k value, your theoretical x values, and the mass of the ball in your experimental data table.
2. Be sure logger pro is set up and you have both distance versus time graph and velocity versus time graph checked as being pulled up on main screen.
3. Be sure launcher is directly below motion detector. Set up launcher to test first displacement (x) value on data table.
4. Push the start button on the logger pro software and listen for the clicking noise of your motion detector. Launch projectile straight into the air towards the motion detector. When the ball returns to the ground, stop the motion detector.
5. Looking at distance versus time graph, look at the graph and subtracted d_{final}-$d_{initial}$ or maximum distance minus minimum distance on furthest of left side of graph to get experimental height value.
6. Record this value in your data table
7. Looking at the velocity versus time graph, record the point of maximum velocity (assuming that the projectile is the fastest at the moment it is launched). It should look like the first peak in your graph because the projectile sped up and then slowed down.
8. Record this value in your data table
9. Save graphs with “group name, ___ distance, trial 1”.
10. Repeat for each “x” value in data table for trial one.
11. Repeat all, for “x” values in data table for trial two.
12. Take averages for all of these values and record on data table.
13. Use the proper Energy equations in order to solve for each energy USING the averages you just collected.
14. Use checklist in order to finish error analysis and percent efficiency of your launcher.

Stage 3 – Learning Plan

Pre-Assessment

How will you check students' prior knowledge, skill levels, and potential misconceptions?

Learning Activities

Day 1 (1/21) – Introduction to Work

Teacher Notes: Work in the general vernacular is used to represent a variety of concepts that often require some form of effort on the part of the worker. In physics, work is done when a force acts upon an object to cause displacement. Work also causes a transfer of energy, but that will be dealt with in the energy and work-energy theorem sections. Students struggle to successfully conceptualize "physics" work unless their prior conception of work is directly confronted. This is the goal of Day 1.

Learning Target: I can define, compare and contrast the amount of work done in various physical situations by qualitatively using the equation, $W = Fd\cos\theta$, and differentiate between positive and negative work in terms of gain/loss in energy.

Check-in: As their check-in, students will be asked to complete a Think-Pair-Share activity where they first work individually and then work with a partner to define work and then to rank four pictures from most to least work and to write one sentence explaining their ranking. The pictures are randomly scattered on the screen in a PowerPoint and include:

- a woman pushing a baby in a stroller
- a person reeling in a fish
- a person pushing on a wall
- a man lifting hand weights

After a few minutes, a whole class discussion will ensue with the goal of sharing and discussing both the ranking and the reasoning. The pictures are deliberately vague (clip art) to encourage students to make, justify, and challenge assumptions.

Lesson: The body of the lesson will focus on defining work conceptually and on qualitative comparisons between various physical situations as a stepping stone to solve the work equation as homework. This portion of the lesson will be teacher-led direct instruction, and it is useful to use some form of organizing document (PowerPoint/Prezi) for various pictures/graphics used to check for understanding. Students will leave knowing:

- Work is the transfer (movement) of energy by one object pushing or pulling another object over a displacement.
- Work only occurs for parts of F and d that are parallel
- Students will learn $W = Fd\cos\theta$
- Will identify work done on/by and +/- work

Post discussion, students are given the definition of work (bullet points 1 and 2 above) and asked to write it down. Subsequently students will be asked to observe various scenarios, acted by student volunteers, which we will classify according to whether each <u>student</u> is or is not doing work and explain why. Student volunteers will be quietly asked to perform activities like the following:

- Push against a wall (no work because no displacement)

- Push a rolling chair around the room (work)
- Carry a book around the room on flat open palm (tricky as the student does no work, but friction does work)
- Iteratively pick up pencils one at a time and set them on top of a stack of books (work)

Once students have mastered the definition of work, the idea of work done on a system (+ work) and work done by a system (- work) will be presented to students. Students will then rank introductory pictures and student demos according to which object has positive work and which has negative work.

The equation for work will be presented as a variable representation of the definition. Students will be asked to determine when the equation will be positive (force and displacement are in the same direction) and when it will be negative (force and displacement are in the same direction).

In the last 7 minutes of class, introduce project using a pre-filmed video, the overview document "Launcher Liveliness: How Your Launcher Uses Energy" and the rubric "Launcher Liveliness Rubric" to allow students sufficient time to gather materials for next Tuesday.

Homework/End of Class Work: Watch Flipped classroom video reviewing work with 3 sample problems and complete work problem set. Due by Wednesday Quiz.

Day 2 (1/22) – What is Energy/Conservation?
Teacher notes: Energy is a concept model that helps us to conceptualize the idea that something (total energy) is conserved as energy transforms in various real world situations. The concept of energy conservation allows us to solve problems because energy/mass is total is constant in the universe. Energy is scalar, abstract (hard to perceive/measure), given meaning in the form of equations, a central scientific concept (more information: http://physics.info/energy/).

Learning Target: I can define conservation and efficiency and differentiate common usage and physics usage of each and I can relate conservation of energy to energy changes that occur in a system.

Check-in: Students will be given several scenarios to classify as true or false with respect to work (i.e. When I learn a new subject, my brain is doing work) and 2 work problems to solve. Student volunteers will come to the document camera and work/explain each problem).

Lesson: The focus in today's lesson is for students to begin using energy related terms (energy, efficiency, conservation) in the context of physics/science. The class will be split into small groups (cooperative learning layout) for the day and students will be posed a series of questions to answer in groups:

1. What is conservation? (Think about real world and science)
2. What is energy?
3. Is energy important? Why?
4. Is energy finite? Can we use it up?

5. How do conservation and energy relate together?

Subsequently, group spokespeople will share their answers to the questions and the teacher will guide the discussion. Ultimately, students must know that energy is a concept model, conservation means conserved, and that conservation of energy allows us to track or predict things that we care about like mechanical efficiency, heat loss, cooling needs and heat death of the universe. Guiding questions:

1. What do you think of when you hear conservation of energy versus conservation of mass?
2. How can they charge me for energy usage in my house if energy is conserved?
3. Where is energy? Why do we say something "has energy?" This is a **unit essential question "Why do things have energy?" phrased in a different way.**

This discussion is intended to take 25-30 minutes with a big sticky or other large paper for recording unanswered questions/concerns/ideas for later consideration.

Note: The teacher will have news/magazine articles on hand for students to read and share along the way about energy conservation, heat, etc. (like this http://ngm.nationalgeographic.com/2009/03/energy-conservation/miller-text/2) to foster a table discussions (in the case of "dead air" time where students are stuck).

Once students have mastered the idea that energy is a concept rather than a physical object, we will discuss how energy is further broken down into categories to assist with modeling (where the trouble is when we seem to "lose" or "use" energy, it has merely transformed). Students will then be challenged to use a concept attainment to determine the classification rule for a specific kind of energy (in this case Kinetic Energy). Instructions as follows:

Concept Attainment (12-15 minutes)

a. Instructions for Concept Attainment (Written on Pull-out Whiteboard to minimize reminders during discussion)
    1. I will present examples and non-examples to you (allow 2-4 minutes)
    2. You will listen and formulate hypotheses (silently) (allow 1-2 minutes)
    3. When you think you have a good hypothesis, raise your hand and I will call on you to offer an example which I will place in the correct column (do this 2 minutes)
    4. After a while, I will begin to ask you which column to place examples in (2 minutes)
    5. When most of you understand the concept, I will ask for a volunteer to state their hypothesis. Please wait until we get to this stage to tell anyone your hypothesis, we want everyone to get a chance to form their hypotheses. (allow 2-5 minutes)
    6. Discussion (5 minutes)

Note: If this is the first time a concept attainment has ever been done, it is helpful to do a practice round with a non-related simple rule for the students to discover like letters made with straight lines (So examples in order would be E (ex), F (ex), G (non-ex), H (ex), I (ex), J (non ex), K (ex), L (Ex), M (Ex…this one throws them off the 2/1/2/1 pattern), N (ex), O (non ex)). Usually, by K, kids are ready to offer letters for you to classify (step 2), if not, prompt at N or O. Frequent reminders not to shout out the answer are important.

My first rule will be Objects with moving(kinetic) energy

Examples:

1. Moving toy car – likely live
2. Runner – likely video
3. Gyroscope
4. Pendulum (moving), Newton's cradle makes a good one
5. Skateboarder
6. Falling object
7. Thrown baseball

Non-Examples (anything non-moving):
1. Sitting person
2. Battery
3. Plant
4. Coiled spring
5. Light
6. Diver on a cliff
7. Ball at the top of a ramp
8. Pendulum tied in a non-equilibrium position (has Ug)

Homework: Complete work problem set. Due by Wednesday Quiz.

Day 3 (1/23) – Energy Types/Conservation and Work Quiz
Teacher notes: Today, post work quiz, the focus will be on classifying energy types as mechanical and non-mechanical, to include all forms of energy (most previously unrecognized by students as energy) like kinetic, gravitational potential, elastic potential, chemical potential, electromagnetic (light), thermal, electrical/magnetic, sound, and nuclear. Subsequently students will be asked to determine energy transformations in live demos.

Learning Target: I can apply my ability to classify energy according to type to differentiate common usage and physics usage of each and I can relate conservation of energy to energy changes that occur in a system.

Check-in: Students will take a 10-15 minute quiz over Work to include recognizing work done on and by objects in various systems, and work calculations.

Lesson: Post quiz, students will be put into groups and given a variety of pictures to classify as possessing primarily kinetic, gravitational potential, elastic potential, chemical potential, electromagnetic (light), thermal, electrical/magnetic, sound, or nuclear energy. After group work time, the class will work together to build a class approved classification for each image. In a round robin fashion, each group will either add or move a picture to a different energy type on the board. When the map is complete and correct, students will be introduced to the further classification of energy as mechanical (has the ability to do work), and non-mechanical, and a thinking map will be developed on the board to represent the breakdown between mechanical and non-mechanical energy and then individual energy types. Once the map is complete, students will observe a series of demos and make a chain map illustrating the energy conversions in an effort to answer**:** **How can energy be transferred from one material to another?** Demos will include:

1. Hooking a hand crank generator to a battery
   (chemical potential ->electrical>thermal, sound, kinetic)

2. Turning a hand crank generator to light a light bulb (Christmas light bulb) (Kinetic -> electrical, sound -> light, thermal)
3. Dropping a bouncy (happy) ball (gravitational potential ->kinetic -> elastic potential/sound -> kinetic -> gravitational potential).
4. Throwing a ball up (kinetic -> gravitational potential ->kinetic -> elastic potential/sound -> kinetic -> gravitational potential).
5. Dropping a non-bouncy (sad) ball (gravitational potential ->kinetic -> thermal/sound)

Homework: Video record or draw your own energy demonstration, describe the energy transformations occurring. Due Monday, be prepared to share with a classmate for feedback tomorrow.

Day 4 (1/24) – Investigating Mechanical Energy Types - Ug/KE/Ue
Teacher notes: The focus today will be on the three types of mechanical energy (gravitational potential, kinetic, and elastic potential). Students will leave class knowing the definition, 3-4 examples, and the equation for each.

Learning Target: I can qualitatively and quantitatively define the three types of mechanical energy (kinetic, gravitational potential, and elastic potential) and give examples of each by working within an expert group to create a lesson about my energy type and then teaching my energy type and learning the other two from my home group.

Check-in: Students will swap energy demonstration recording/drawing ideas with a partner and give warm/cool feedback.

Lesson: Students will be split into groups of three for home groups. Within their home groups, they will assign one person per energy type. Then groups will split into expert groups and begin investigating their energy types. Available resources will include the textbook, printed copies of AP notes, and online resources including the physics classroom. Each expert group will need to create a Prezi or video to share with their home groups. The Prezi or video should include the definition of the energy type, 3-4 examples in visual form, the equation and the meaning of each symbol, and a fully worked step-by-step example problem. Students will report definitions, examples, and equations to home groups in the last 15 minutes of class (example problems will be used tomorrow).

Day 5 (1/27) – Calculating Mechanical Energy Types (Ug/KE/Ue)
Teacher notes: The focus today will be on using the equations for three types of mechanical energy (gravitational potential, kinetic, and elastic potential). Students will leave class having worked at least 3 problems of each type.

Learning Target: I can use the equations for kinetic energy, gravitational potential energy, and elastic potential energy to solve for energy, velocity, mass, height, spring constant and spring displacement in word problems.

Check-in: Students will return to expert groups to review their example problems.

Lesson: Students will be seated cooperatively in their home groups. Students will teach each other the example problem for their energy type. We will start with kinetic energy with 10 minutes of teaching time followed by one group practice problem and one individual practice problem of each type. The remainder of class will be spent working additional energy problems in small groups.

Homework: Practice solving energy problems using video resources from classmates and issued problem set with posted solutions to prepare for quiz on Wednesday. Bring any materials need for tomorrow's launcher day.

Day 6 (1/28) – Alter and Describe Day

Teacher notes: The focus today will be repairing/altering the launcher to prepare for the energy performance task. See "Build Day 3: Energy Revisions Checklist" for details.

Learning Target: I can repair/revamp/alter my launcher as described in the Build Day 3: Energy Revisions Checklist to prepare to evaluate the energy efficiency of my launcher.

Check-in: Students will work two energy problems on whiteboards – problems from assignment that students need assistance with.

Lesson: Students will be given the period to work on launchers and update their launcher design document with available supplies (minimum: hot glue guns, wood glue, scissors, box cutters, screw drivers, needle nosed pliers, permanent markers, rulers, cameras, and computers).

Homework: Continue to practice solving energy problems using video resources from classmates and issued problem set with posted solutions to prepare for quiz on Wednesday.

½ day (1/29) – Calculating KE, Ug, and Ue Quiz:

Teacher notes: This is an early release with shortened classes, thus students will complete a quiz to demonstrate mastery of KE, Ug, and Ue calculations.

Learning Target: I can use the kinetic energy, gravitational potential energy, and elastic potential energy equations to solve for energy, velocity, mass, height, spring constant or spring displacement on my quiz.

Check-in: Begin Quiz

Lesson: Students will work on quiz through the end of the period. Those finished early may watch the flipped classroom video assigned for homework

Homework: Watch Flipped Classroom video relating work and energy and complete associated notes.

Day 7 (1/30) – – Work/Energy Theorem

Teacher notes: Today students will learn how work relates to energy through the work energy theorem. $W = \Delta KE$ *or* $W = ½mv_f^2 – 1/2mv_i^2$

This is best done by having students work a guided example problem using their knowledge of work and kinematics and then showing them the more direct work/energy theorem solution. This is one of the times when work/energy makes their lives easier.

Check-in: Students will work a seemingly mid-level difficulty force/kinematics problem broken into easy step-by-step instructions. Problem: A 0.5 kg cart applies a force of 6 N to a 0.1 kg stack of blocks and moves them 0.2 m.

a. How much work does the cart do on the blocks?
b. What is the acceleration of the blocks (kinematics!)?
c. What is the final velocity of the blocks (kinematics!)?
d. What is the change in kinetic energy of the cart?
e. How do a and d relate?

Lesson: ***Essential Question:*** **How can energy be transferred from one material to another?** Students will be seated cooperatively. Subsequent to the check-in, we will review the solution and then the students will be asked to consider whether we can use energy and work to solve this problem in an easier way. I usually demonstrate the example problem with wooden blocks and a dynamics cart. Guiding questions:

1. When the cart did work on the blocks, what did they do? (move)
2. What kind of energy does this relate to? (kinetic)
3. So the cart had what kind of energy before it hit the blocks? (kinetic)
4. After the cart hit the blocks, what did the cart do? (stopped)
5. So, did the cart gain or lose energy? Do + or – work? (lose, - work)
6. So who got the + work? (blocks)

The goal is to get students to relate negative work with a negative change in kinetic energy and positive work with a positive change in kinetic energy. After students agree to this relationship (may require more demos: lifting weights, using a pulley and motor to lift something), it is time to present the work kinetic energy theorem, $W = \Delta KE$ *or* $W = \frac{1}{2}mv_f^2 - 1/2mv_{i.}^2$ Then we will alternate completing a structured problem set using guided and small group practice.

Homework: Practice solving work-energy theorem problems in issued problem set.

Day 8 (1/31) – Work/Energy Theorem Calculation Practice

Teacher notes: The focus today will be on incorporating the work-energy theorem with the other types of energy problems to correctly identify the problem type, chose the appropriate equation, and perform the appropriate operation.

Learning Target: I can use the equations for kinetic energy, gravitational potential energy, and elastic potential energy and/or the work-energy theorem to solve for work, force, distance, energy, velocity, mass, height, spring constant and spring displacement in word problems.

Check-in: Review of homework problems.

Lesson: Students will select ten or more problems to solve from a class set of mixed kinetic energy, gravitational potential energy, elastic potential energy, and work energy theorem problems to work independently. Problems will be setup in manila folders with the problem on the outside, and the solution on the inside. Some solutions will also be available in video form on the website. Students will retrieve a problem, work it, check it, and return it. During this time, individuals who are struggling, have been absent, or are advanced will get individual attention/assistance.

Homework: Practice solving mixed energy and work-energy theorem problems in issued problem set. Online quiz.

Day 9 (2/3) - Conservative/Nonconservative Forces and Energy

Teacher Notes: The work done by a *conservative force* is path independent and depends only on the initial and final position of the object. For mechanical systems involving only conservative forces, the total mechanical energy remains constant and is the sum of KE and PE. An example of a conservative force is gravity. Non-conservative forces are path dependent, and work done is influenced by the path taken. Friction is an example of a non-conservative force. For systems with non-conservative forces, the work done by non-conservative forces is equal to the change in mechanical energy or $W_{NC} = E_f - E_o$. Non-conservative work due to friction will always be negative because the system will lose mechanical energy (which converts to primarily to thermal energy in the system and in the object doing work, but also to other forms of energy). The non-conservative work will equal the total amount of energy converted from mechanical to non-mechanical. Non-conservative work decreases the efficiency of machines and systems by decreasing the Work or Energy out because some portion of the thermal energy is unrecoverable to use to do work.

Learning Target: I can differentiate between systems with conservative and non-conservative forces and describe the molecular consequences of these energy transformations in systems where non-conservative work is done.

Check-in: Students will be shown two scenarios of a skateboard, one without friction and one with friction, using the skate park PhET Colorado simulation (http://phet.colorado.edu/en/simulation/energy-skate-park-basics) and asked to explain the energy transformations for each.

Lesson: **Essential Questions: What happens to a material when it receives energy? What happens to the energy in a system — where does this energy come from, how is it changed within the system, and where does it ultimately go?**
This will be a primarily direct instruction/whole class discussion day. Post-check in, students will be introduced to the idea of conservative and non-conservative forces and to relate non-conservative forces to work done by the system. Friction will be highlighted as the primary cue to a system that has non-conservative forces and thus transforms some mechanical work into non-mechanical energy (equivalent to non-conservative work). While frictionless (also ice, friction may be neglected, smooth) will be highlighted as the primary contextual cue to assume conservation of mechanical energy. To check for understanding, student pairs will be given various scenarios and asked to classify the system as one with that obeys conservation of mechanical energy ($W_{NC} = 0$ J)or one where non-conservative work must be considered ($W_{NC} \neq 0$ J). Systems for classification include:

1. A block sliding down a smooth plane
2. A car coasting up a hill
3. A car coasting down a hill covered in ice
4. A ball falling through the air assuming no drag
5. A ball falling through the air

Once students have demonstrated an ability to classify systems, the equation $\Delta ME = W_{NC}$ ($\Delta ME = 0$ J for systems where $W_{NC} = 0$ J), we will revisit the skate park PhET Colorado simulation to utilize the bar graph feature and observe the energy transformations in graphical form. Students will ultimately use whiteboards to predict the energy graphs for various scenarios (multiple hills, etc.) for systems with and without friction.

Homework: Draw a skate park system with at least 3 hills or loops and draw the energy graph for each assuming a frictionless system on a separate page.

Day 10 (2/4) –Calculating Energy in Systems with Conservative Forces
Teacher Notes: To implement the activity, students will need a computer with the PhET Colorado skate park simulation, a printed large picture of the track simulation (screen capture) with pertinent measurements (initial height) clearly marked, and access to files with each track already built to verify solutions.

Learning Target: I can use the law of conservation of energy to solve for kinetic energy, gravitational potential energy, height, and velocity at multiple points in skate park system.

Check-in: In pairs, students will exchange skate park systems (just the drawing) and draw energy graphs for their partner's system. Subsequently they will compare answers, discuss and share.

Lesson: This will be a primarily student directed cooperative activity. Students will be placed in groups of 3-4 students and given a set of roller coaster problems based on the PHeT simulation. The first simulation will be done as a whole class demonstration to ensure that students know how to check their answers by opening the track specific files, turning off friction, turning on the energy vs. time graph, and reading numbers of the graph. Note: students should be encouraged to use the pause function. Students will be using the following format (used throughout the year) to solve problems:

- Step 1: Identify the problem type (i.e. Conservation of Energy or Conservation of Mechanical Energy)
- Step 2: Write out givens (in this case, draw a picture and write the givens for each point on the picture)
- Step 3: Determine and write your unknown(s) at each point
- Step 4: Find and write formula(s) need to solve each point
- Step 5: Show your work for each point
- Step 6: Box your solution with units

The primary purpose of today is practice in a low stakes environment. Informal checks for understanding will occur throughout the class period. Students will also be solidifying skills in calculating energy which will be on tomorrow's exam. The last 10 minutes of class will be dedicated to assisting students with gathering resources to study for tomorrow's exam ("how I would study for tomorrow's exam is…")

Homework: Study for 3 week Exam using problem sets, notes, and 3 quizzes

Day 11 (2/5) – 3 Week Exam – Work, KE, Ug, Ue
Teacher Notes: To assist with common planning and offering access to high standard curriculum to all students, we will give our 3 week common exam on this day. This exam will be multiple-choice focusing on conceptual and quantitative problems over work, kinetic energy, gravitational potential energy, elastic potential energy, and the work-kinetic energy theorem. Conservation of energy calculations are beyond the scope of this assessment, but the free response portion of the test will ask students to 1. Describe the energy transformations in 2 systems and 2. Draw qualitative graphs describing energy

transformations for a roller coaster (skate park) system).

Learning Target: I can demonstrate my ability to describe systems in terms of work, kinetic energy, gravitational potential energy, elastic potential energy, energy transformations, and the work-kinetic energy theorem and I can solve problems using the associated equations for each on my 3 week exam.

Check-in: Brief warm up. 2 misconception type questions that have been persistent throughout unit (i.e. T/F An object can only have kinetic or potential energy at a given point in time.)

Lesson: Students will complete the multiple choice and free response portion of their exam during class.

Day 12 (2/6) – Pendulum/Roller Coaster Calculation Practice
Teacher Notes: This day is similar to day 10, but students will also investigate pendulum systems. Students will work in cooperative groups and have an end of class whiteboard quiz. Whiteboard quizzes allow students to work a problem that I either write on the board or prepare in a PowerPoint for a quiz grade. To implement the activity, students will need access to problems (at this point, I will use primarily word problems and a coke bottle pendulum demo).

Learning Target: I can use the law of conservation of energy to solve for kinetic energy, gravitational potential energy, height, and velocity at multiple points in a roller coaster or pendulum system.

Check-in: Students will individually attempt a new skate-park problem and solve for the top, the bottom and an intermediate point.

Lesson: This will be a primarily student directed cooperative activity. Students will be placed in groups of 3-4 students and given a pendulum problem and asked to find a method for solving for 3 points without instruction for 5 minutes. This will be followed by a whole class discussion of how to solve the problem, solving the problem and then giving students a series of problems to solve. The primary purpose of today is practice with students building confidence in their ability to work conservation of energy problems. The last 10 minutes of class will be a Conservation of Mechanical Energy whiteboard quiz.

Homework: Pendulum and rollercoaster problems practice in both paper and online format – Assignment is to work until independently successful on one problem of each kind. Solutions posted online in full worked out video and just answers formats.

Day 13 (2/7) – Conservative Forces – Ideal Mass/Spring Systems (KE, Ug, Ue)
Teacher Notes: This is the day we will introduce ideal mass/spring systems. This will be direct instruction with students working on whiteboards or in notes according to preference. This requires the setup of a simple Hooke's Law system (http://www.clemson.edu/ces/phoenix/labs/124/shm/) so students can see a mass/spring system in action. Note, we typically neglect Ug in these systems because it is a small portion of the system energy. The demo/lecture will help students to understand why this is acceptable (applicable for launchers).

Learning Target: I can use the law of conservation of energy to solve for kinetic energy, gravitational potential energy, elastic potential energy, height, spring displacement, and velocity at multiple points in a roller coaster or pendulum system.

Check-in: Students will be shown a video of the Hooke's Law apparatus in motion and asked to identify the energy transformations. And, given the k of the spring, to calculate the maximum elastic potential energy of the system.

Lesson: This will be a direct instruction day. 20-30 minutes will be dedicated to solving the mass spring demo system as a class. 20 minutes will be allowed for students to solve similar problems independently.

Homework: Work a mass-spring system without Ug and do 10 minute PreLab using flipped classroom video.

Day 14 (2/10) – **Theoretical calculations (launcher)**
Teacher Notes: This is the day when students will calculate the energy conversions in their launcher system. Based on yesterday's lesson, students will be asked to justify their choice to include or neglect the effects of gravitational potential energy when converting the elastic energy into kinetic energy during the launch.

Learning Target: I can use the law of conservation of energy to solve for kinetic energy, gravitational potential energy, elastic potential energy, height, spring displacement, and velocity for my launcher system.

Check-in: Homework review

Lesson: This will be a cooperative learning day with launchers, students will use the "Theoretical Energy Calculations Checklist" to complete their work. An available example for a system with a much smaller spring will be available in class and electronically.

Homework: Complete theoretical calculations and pre-lab.

Day 15 (2/11) – Lab 1: Non-conservative Forces Roller Coaster Lab
Teacher Notes: This is the day we will reintroduce real world energy systems with non-conservative forces acting on the object (in this case friction). To do so, the students will complete a rollercoaster lab similar to the one found at this link: http://www.stanford.edu/group/lpchscience/cgi-bin/wordpress/images/2012/11/Potential-and-Kinetic-Energy-T.pdf, though materials will be pre-prepared and available to students on lab day. Students will be assigned a pre-lab for homework. Using a flipped classroom video, students will be challenged to predict various scenarios that they will later test in the lab.

Learning Target: I can use a real-life roller coaster model to investigate the law of conservation of energy in a real world system with non-conservative forces.

Check-in: Check pre-lab at the door and send to lab stations.

Lesson: **Essential Questions: What happens to a material when it receives energy? How does the flow of energy affect the materials in the system?**
Students will create a foam rollercoaster according to lab instructions (plan to be a modification of http://www.stanford.edu/group/lpchscience/cgi-

bin/wordpress/images/2012/11/Potential-and-Kinetic-Energy-T.pdf). After 15 minutes of setup time in class, students will run trials, gather data, and complete calculations. In the last 5 minutes of class, we will decide if the system conserves mechanical energy.

Homework: Complete post-lab using flipped-clasroom video

Day 16 (2/12) – Temperature, Thermal Energy, and Heat and Nonconservative Forces
Teacher Notes: This day focuses on differentiating between temperature, thermal energy, heat, and explaining how these concepts relate to the work done by non-conservative forces and the seemingly "lost" energy in these cases. Students will need to conceptualize thermal energy as the random molecular kinetic energy of a system, temperature as a measure of the average kinetic energy of the molecules in an object, and heat as the transfer of energy due to a temperature gradient that can flow through 3 mechanisms (conduction, convection, and radiation). Students will likely be most successful in visualizing conduction where hot (fast moving) molecules bump into cold (slower) molecules and do work on them (thus the faster molecule loses kinetic energy and slows while the slower molecule gains kinetic energy and speeds up), but should understand the basics of convection and radiation. Convection is similar to conduction, but occurs in fluids that can flow due to a density gradient. Radiation is more complex to visualize as it involves the use of electromagnetic waves and photons (discussed 4th 9 weeks), but students will be introduced to the idea here (dual nature of light). Heat transfer is outside the scope of the AP standards for year one of Physics B, but is a supporting standard in the TEKS. It will be useful to keep one roller coaster setup at the front of the room for reference.

Learning Target: I can describe how macroscopic and microscopic behavior interact to explain how the work done by friction transformed some of the mechanical energy in my rollercoaster into thermal energy, raising the temperature, and ultimately leaving my system through a heat transfer mechanism.

Check-in: Students will be asked a series of guiding questions which they will answer, discuss with a partner, and share at the appropriate time during the discussion. Guiding questions:

1. Mechanical energy was not conserved in your roller coaster, and we know that total energy is conserved, so what did that "lost" mechanical energy due to the work done by friction turn in to? (sound, thermal)
2. Based on your answer in 1, what could we measure to find out if you are correct?
3. What is temperature?
4. Can you sense temperature?

Lesson: **Essential question: What happens to a material when it receives energy?** Beginning with the discussion of the rollercoaster, the discussion will be steered towards the understanding that the primary non-mechanical energy present near the end of the coaster due to the work done by friction was thermal energy, and that thermal energy should correspond with an increase in temperature of both the ball and the foam (Good visual: http://phet.colorado.edu/sims/friction/friction_en.html, good kinesthetic: rubbing hands together to generate warmth). Next, we will investigate temperature and thermal energy on a molecular level using the States of Matter applet from PhET Colorado (http://phet.colorado.edu/en/simulation/states-of-matter-basics, the phase change tab). The goal is for students to know that adding energy (heat) increases the thermal energy (randomized molecular kinetic energy or wiggle), and that temperature measures the average kinetic energy (can have more molecules and same temperature). I can have Subsequent to this understanding, we will probe the idea that measuring temperature of the ball and foam would show us the thermal energy. Probing questions: Was the ball and/or foam hot at the end? Should it have been? Can you accurately measure that by touch? Demonstration: students alternate between touching the metal part and top of their desks and discuss the "temperatures" of each. Eventually students should arrive at the conclusion that they can't accurately sense temperature. Rerun ball down foam track and measure before/after with a temperature gun (if available). Ask students to explain why temperature is still low. Lead into discussion of heat vs. temperature, and explain that heat is leaving the system via primarily convection. This is an exploration and students are expected to understand at the describe level.

Homework: Complete flipped classroom exercise asking students to describe heat, temperature, and thermal energy in various video clips using the States of Matter Simulation.

Day 17 (2/13) – Conservation of Energy with Nonconservative Work Practice
Teacher Notes: This day is similar to day 10, but students will be practicing conservation of energy problems in systems with nonconservative work. We will primarily use AP Physics B free response and multiple choice problems (http://www.allenisd.org/cms/lib/TX01001197/Centricity/Domain/1757/6%20Work%20and%20Energy.pdf).

Learning Target: I can use the law of conservation of energy to solve for work due to nonconservative forces, force kinetic energy, gravitational potential energy, height, and velocity in real-world problems.

Check-in: Discussion/sharing of homework

Lesson: This will be a primarily direct instruction/practice day. I will model working one problem and then ask students to work in pairs to model a similar problem to work as many problems as possible (likely 2 rounds).

Homework: Work problems in problem set (ongoing).

Day 18 (2/14) – COE with and without Nonconservative Work Practice
Teacher Notes: All energy problems are on the table for today's practice.

Learning Target: I can use the law of conservation of energy to solve for work due to nonconservative forces, force kinetic energy, gravitational potential energy, height, and velocity in real-world problems.

Check-in: Discussion of first 2 problems, conservation of mechanical energy or has non-conservative forces.

Lesson: This will be a primarily direct instruction independent practice day following from Day 17. Students will work in pairs or alone.

Homework: Complete Pre-lab using flipped classroom video.

Day 19 (2/18) – Lab 2: Measure Actual Results

Teacher Notes: This is the day when students will measure values to verify the energy conversions in their launcher system.

Learning Target: I can use the law of conservation of energy to solve for kinetic energy, gravitational potential energy, elastic potential energy, height, spring displacement, and velocity for my launcher system.

Check-in: Homework review

Lesson: This will be a cooperative learning day with launchers, students will use "Lab 2: Energy & Non-Conservative World" and "Actual Energy Measurements Checklist" to complete their work. An available example for a system with a much smaller spring will be available in class and electronically.

Day 20 (2/19) – Compare Theoretical and Measured Values and Develop a Predictive Model

Teacher Notes: This is the day when students will compare their theoretical and measured (actual) results for their launchers in an attempt to develop a predictive model for use on launch day.

Learning Target: I can calculate the error between my theoretical and measured values for the maximum height and velocity achieved by my launcher and use this information to create a predictive model (graphical or equation) that I can use to determine the spring displacement (x) I need to achieve a given height (h).

Check-in: Review of percent error calculations

Lesson: **Essential Questions: What happens to the energy in a system — where does this energy come from, how is it changed within the system, and where does it ultimately go?**

This will be a cooperative learning day with launchers, students will use "Error: Theory vs. Reality Checklist" to complete their work. An available example for a system with a much smaller spring will be available in class and electronically.

Day 21 (2/20) – Power

Teacher notes: Today students will learn about the rate of work done or energy transfer, also called power. P = W/t or P= Fv.

This is best done direct instruction followed by students working progressively more difficult power problems.

Check-in: Conservation of Energy with Non-Conservative Work Quiz

Lesson: After the quiz, students will be asked to discuss the concept of power with a partner. Guiding question: What is power? Subsequently, the physics definition of power will be discussed and students will participate in guided problem solving, and then independent practice with simple power problems (resource: physicsclassroom.com)

Homework: One moderate Power problem with flipped classroom video resource.

Day 22 (2/21) - Power
Teacher notes: Today students will practice mid-level difficulty power problems

Check-in: Review of homework problem

Lesson: Students will work in cooperative groups to solve power problems that are AP Physics B multiple choice and free response level.

Homework: One Power AP free response problem with flipped classroom video resource.

Day 23 (2/24) – Review/Problem Practice Day
Teacher notes: Today students will take a quiz over power and then independently practice work, energy, conservation of energy, and power practice problems as a review of the unit.

Check-in: Review of homework problem

Lesson: Students will begin class with a Power Quiz. Subsequently, students will work in independently to solve problems from a mixed bank of available problems with solutions.

Homework: Prepare for Launch Day

Day 24 (2/25) - Lab 3: Performance Task Day
Teacher Notes: This is the day when students will check their predictive model against reality. The teacher will need a large paper with target regions according to rubric clearly marked. This paper will be moved up and down the wall as needed. Further a video camera will need to be on hand to record results in the event of a disagreement.

Learning Target: I can use my predictive launcher model to launch a ball to a height given to me by my teacher.

Check-in: Review of safety rules, and the one chance shot for the performance day.

Lesson: This will be a whole class performance day where the teacher will assign each student group a height to achieve. Students without a predictive model are disqualified from the reaching the height bonus, but will still be allowed to test their theory. Each group will be given a height to achieve that is within the reasonable range for the predictive model developed by that group.

Day 25 (2/26) – 6 Week Exam
Teacher Notes: To assist with common planning and offering access to high standard curriculum to all students, we will give our 6 week common exam on this day. This exam will be multiple-choice focusing on conceptual and quantitative problems over work, kinetic energy, gravitational potential energy, elastic potential energy, the work-kinetic energy theorem, and conservation of energy. The multiple choice will be 20 questions be similar to the 3 week exam in scope with the addition of 2 simple conservation of energy problems. The free response will be a choice of 2 AP free response conservation of energy problems. Each will have a friction component.

Learning Target: I can demonstrate my ability to describe systems in terms of work, kinetic energy, gravitational potential energy, elastic potential energy, energy transformations including conservation of energy, and the work-kinetic energy theorem and I can solve problems using the associated equations for each on my 6 week exam.

Check-in: Brief warm up. 2 misconception type questions that have been persistent throughout unit (i.e. T/F An object can only have kinetic or potential energy at a given point in time.)

Lesson: Students will complete the multiple choice and free response portion of their exam during class.

Resources:

1. **PBS Video Energy Conversions:** http://www.pbs.org/opb/circus/classroom/circus-physics/conservation-energy/
2. Cool physics blog with day to day descriptions: http://mrhallphysics.edublogs.org/page/2/
3. Hooke's Law http://www.4physics.com/phy_demo/HookesLaw/HookesLawLab.htm
4. Physics Simulations: http://phet.colorado.edu/en/simulations/category/new
5. Roller Coaster Lab: http://www.stanford.edu/group/lpchscience/cgi-bin/wordpress/images/2012/11/Potential-and-Kinetic-Energy-T.pdf