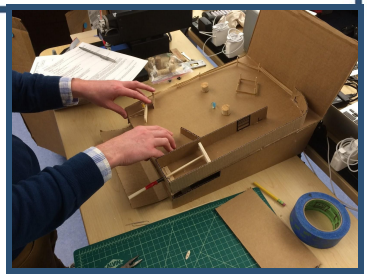
SCOPES-DF

Fab Tested

Pinball Machine Lesson (Understanding Energy)[1]

(Teresa Sappington, Lamar County Technical Center, Purvis, MS)



Student Mastery Level X Advanced
Educator Experience X Advanced

Targeted Age/Grade	Original Context	Subjects	Instructional Time	Digital Fabrication Tools
15 / 9th grade (high school)	• In classroom • Special project in Fab Lab or Makerspace • Capstone • Group project	Science Technology Engineering Arts	2 hours	Laser Cutter Vinyl Cutter (for **extension** activities) 2D Vector Graphic Software

Overview

Snapshot: Build some unique energy for physics and math by designing simple and complex machines, in the form of an old school arcade pinball games

Tags: Physics, motion, energy

Collections: Fab Tested, Games

Summary

A 9th grade class can learn conceptual physics as students explore digital fabrication tools to design a pinball machine. When they laser cut their prototypes, students will gain an understanding of the applications of potential, kinetic and mechanical energy through simple and complex machines.

[1] Adapted from Teressa Sappington, Engineering Instructor, Lamar County School District original lesson plan "Pinball Machine" for 9th Grade Conceptual Physics.

Lesson Objectives

By the end of lesson, students will:
- Design and build a pinball machine utilizing fab lab tools.
- Understand how elastic potential energy, levers, and force are used.
- Understand the concepts related to work and energy.

Details

Lesson Overview (for students):

All mechanical energy is classified as either kinetic or potential. As students explore digital fabrication tools to design a pinball machine, they will gain an understanding of the applications of potential, kinetic and mechanical energy through simple and complex machines. By end of lesson, students will be able to design and build a digital fabrication pinball machine that will use at least one form of energy.

Key Concepts

Conceptual Physics (9th Grade)

Conceptual Physics presents concepts of the major themes of physics. There are two ways that beginning students of physics can understand the topic: (a) through mathematical models, and (b) through concepts. This course takes the latter approach. The concept of energy is often introduced in the very first unit of 9th grade Conceptual Physics. Energy is a critical concept across all science disciplines and as such serves as both a disciplinary core idea in multiple disciplines and a crosscutting concept. It is essential for explaining a wide range of phenomena, solving problems that occur in everyday life, and learning other science ideas. For these reasons, energy plays a central role in the high school science curriculum.

Instructional Design**: Confirmation Inquiry Level 3**

Key Vocabulary Words:

Work, Joule, Power, Energy, Lever, Pulley, Force, Motion, Mechanical Energy, Potential Energy, Elastic Potential Energy, Chemical Energy, Gravitational Potential Energy, Kinetic Energy, Work-Energy Theorem, Law of Conservation of Energy, Machines, Efficiency, Watt, Horsepower

Key Concepts:

Energy
- Energy is defined as the capacity of a physical system to perform work.
- The Law of Conservation of Energy states that energy can neither be created nor destroyed. If you think energy has ‘disappeared’, it has not has been converted to a different type of energy.

- There are two types of mechanical energy: kinetic and potential. Kinetic energy is the energy of motion and potential energy is stored energy.
- Energy can be stored. Stored mechanical energy can be seen in rubber bands that are stretched.
- Energy can be converted. Stored energy can be converted to motion by releasing a spring or rubber band.

Forces and Motion

- Force is a push or pull on an object which changes direction of speed of motion.
- The flipper in the pinball machine changes the marbles' speed and direction of motion.
- The force of gravity accelerates the ball down the incline of the pinball machine.

Levers

- A lever is a simple machine that makes work easier for use by decreasing the force required to do work.
- Levers involve moving a load around a pivot using effort.
- The effort needed to lift a load is decreased, however the distance is larger. In turn the load is larger while the distance moved is smaller.
- A bell crank is a lever with two arms that have a common pivot at their junction.
- The bell crank on your pinball machine transfer horizontal force to vertical force.

Key Formulas

WORK = FORCE (X) DISTANCE
(W) WORK is the amount of FORCE needed to move an object a certain distance. Calculate the force in Newtons. (N) Work is done only when FORCE causes a change in the motion of an object.

JOULE = A Unit of WORK
(J) 1 N (x) m = 1 J (N = Newton)
1 Kg (x) m2/s2 = 1 J (Kg = Kilograms)
You will use the formula for Newtons (N) (X) distance in meters (m) equals JOULES (J). You will convert your mass to a FORCE in Newtons (N), then move the mass a certain distance in meters. The answer to the problem will be in JOULES of energy

ENERGY = The ability to do WORK
(E) Energy is measured in Joules
Law of Conservation of Energy = Energy cannot be created nor destroyed.
Energy is our potential to do some type of work. We use energy constantly.

GRAVITY = Force of attraction between the two bodies of matter due to their mass. The Earth exerts a force on you of 9.8 m/s2. This is a constant and always applies, except in space.

Materials:

- Brads or bolts and nuts
- Corrugated cardboard

- Posterboard
- File folder
- Hot glue gun and sticks
- Large popsicle sticks or paint stirrers
- Marble
- Push pins
- Rubber bands
- Skewers
- Miscellaneous small toys and objects
- Paintbrushes and paints (for decoration)

Digital Fabrication tools used:

- Laser Cutter
- Vinyl Cutter (for extension activities)
- 2D Vector Graphic Software
- Adhesive Vinyl (for extension activities)

Design Files: https://drive.google.com/open?id=0B3tPBZnliO7bX1Q4bWY2ckhHWjg

Step One

Step One: ***Teaching Phase: How will the teacher present the concept or skills to students?***

1. Show students examples of pinball machines by showing the following videos:
   https://www.youtube.com/watch?v=gnrrbKFWL3Q
   https://www.youtube.com/watch?v=jqwOaPYjKXI (min 11:57-end)

2. After watching the video, discuss the motion of the flipper. The flipper transfers energy to the ball to keep the ball in motion. Discuss with students how pinball machines are controlled with electronics so the energy transfer is electrical to mechanical.
3. Show that the transfer of energy in their cardboard pinball machine will be elastic to mechanical.
4. Point out that the travel of the ball is interrupted by bouncing off obstacles. These obstacles make the play more interesting.
5. Show that there is a launcher mechanism off camera that causes the ball to launch into the playing field. The launcher gives the ball the initial speed on the playing field.
6. Discuss the rubric for the activity.

Step Two

Step Two: ***Making the base*** **(Time 30-60 minutes)**

1. Cut a rectangle out of corrugated cardboard to the desired size.

This is usually 18-24 inches long and 13-16 inches wide.
2. Cut some long strips of cardboard to make the 4 sides. These sides will keep the marble on the playing field.
3. Glue the strips around the perimeter of the board.
4. Add cardboard ramps, cardboard obstacles, or small toys around the board to create obstacles or rebound surfaces. Students can also make their pinball machine themed with vinyl decals if time, materials and equipment permit.
5. Cut angled cardboard pieces to attach to the bottom of the base to provide an angle for the playing field. A fast board has about 12-15 degree slope. A slower board has about 5 degrees slope.

6. The included design files have all of the necessary components for an 16 inch x 10 inch base with a 10 degree slope and is capable of being made on an Epilog Mini 24”x12” laser cutter common in many Fab Labs. **The file may have to be modified to work with your local equipment.**

Teacher Led Discussion: Gravitational potential energy depends on the height of an object above the ground. In the pinball machine a larger angle results in a larger gravitational potential energy therefore larger kinetic energy. Because KE = ½ mv^2 higher kinetic energy translates to higher speed.

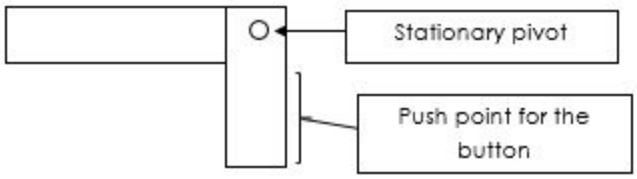
Step Three

Step Three: *Making the flippers* (Approximately 30 minutes required)

Teacher Led Discussion: A bell crank mechanism transfers horizontal motion to vertical motion. Show student videos of bell crank mechanisms in motion.

- https://www.youtube.com/watch?v=-nuAhMMAbXw,
- https://www.youtube.com/watch?v=26D-_Fo0TIk.

1. For the pinball machine, the short leg is attached to the push button from the side of the pinball machine. This is the horizontal motion. The long leg has vertical motion and bats the marble back onto the playing field. Essentially a bell crank mechanism is two levers attached at a stationary point.



Basic Bell Crank

2. Make a single L-shaped flipper from cardboard. This is a basic bell crank mechanism. A good starting point is for the long part of the L to be 3 inches and the short part 2 inches.
3. Drill a stationary pivot hole in the corner of the single layer flipper.
4. Test the flipper shape, size, and placement of the pivot and push button points. Your goal is to have a small horizontal motion, with a small force

required and a fast vertical motion to give the ball more speed.

5. Once you have decided on your design, build two final flippers by gluing 4 layers of cardboard together.
6. Cover the front of the flipper with poster board to give the marble a good surface for bouncing. The included design file has the components for two sets of flippers and is capable of being made on an Epilog Mini 24”x12” laser cutter common in many Fab Labs. The file may have to be modified to work with your local equipment.

Step Four

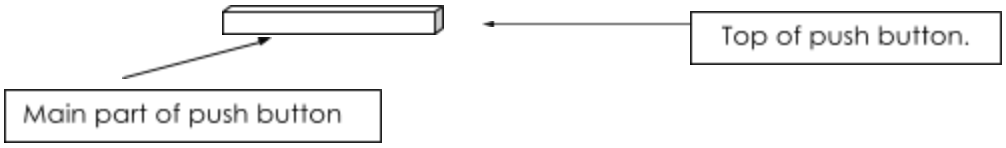
Step Four: *Make Push Buttons* (Approximately 15 minutes required)

1. Cut small rectangles about three inches above the bottom edge of the box.

2. Cut and glue long strips of cardboard to make the main part of the push button. (See diagram below)

3. Make small squares off cardboard to glue on the end to make top of the push button. This will be the part that the player will use to activate the mechanism.

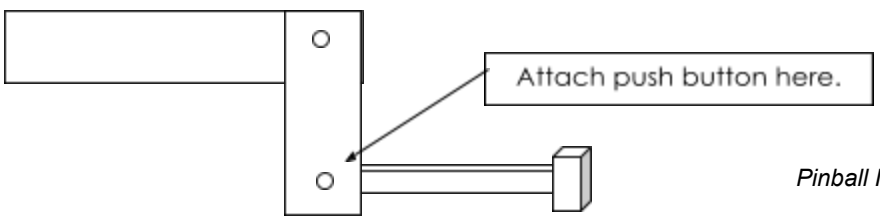
4. Place the push buttons in the rectangular slots on the playing field (created in #1)



Step Five

Step Five: *Attaching the button to the flipper* (5 minutes required)

1. Attach push button to the flipper in the location determined in Activity 2. Use brads, bolts, or skewers that will allow the pushbutton and flipper to rotate. You will need to come up with a design to effectively attach the buttons to the flippers. The basic design is shown below.



2. Add rubber bands to flippers and buttons provide a return force. Play with the arrangement of the rubber bands to find the best return force and smoothest flipper motion.

Teacher Led Discussion: The arrangement of the rubber bands is very important. When the button is pressed the rubber bands should be stretched. The work done in moving the button transfers energy to the rubber bands. That energy is then released when the button is released and the rubber bands pull the flipper mechanism back to its original position. Some of the energy is transferred to the marble on the playing field.

3. Once you are satisfied with the arrangement of rubber bands, flipper, and buttons, permanently attach the flipper mechanism to the playing field with a bolt, skewer, or dowel through the stationary point.

4. Glue cardboard strips to the playing field to provide guides for the push button.

5. The included design files also incorporate push buttons.

6. Measure distance between where the button attaches to the flipper and stationary pivot: _____
7. Measure distance between where the marble hits the flipper and stationary pivot: _____
8. Find the IMA which is the ratio of the two distances (6 divided by 7): _____

Step Six

Step Six: *Making a launcher* (5 Minutes required)

Teacher Led Discussion: The most common launcher for a pinball machine is a spring system, as seen in the picture to the right[1]. A spring system is very similar to a rubber band system because they both convert elastic potential energy to kinetic energy. A spring system can be stretched or compressed to gain elastic potential energy; however, a rubber band system can only be stretched. In the following directions, students will create a rubber band launcher. In the rubber band launcher pulling the paddle does work on the launcher mechanism creating elastic potential energy. When the system is triggered, the elastic potential energy is converted to kinetic energy putting the ball into motion. Students can develop alternate ball launching mechanisms such as a gravity ramp launcher or spinner launcher.

Picture from www.Pinballdecals.com

1. Fold out a file folder and roll it up to make a launching tube.
2. Glue a circular cardboard piece, slightly smaller than the launching tube, to the end of a dowel rod, paint stirrer, large craft stick, pencil, or similar long cylinder.
3. Place the plunger made in #2. Attach a rubber band from the top of the file folder tube to the plunger.

To change the speed of marble launch, change the type of rubber band and placement of the rubber band on the plunger.

4. Attach the launcher to the side of the pinball board.
5. Cut a square hole in the side of the top of the cardboard base.
6. Attach a flat piece of cardboard and a curved piece of cardboard to carry the ball from the launcher to the playing field.

Step Seven

Step Seven: *Making a ball catcher* (5 Minutes required)

1. Cut a 3 inch long x 1 inch high slot in the bottom of the playing field for the ball catcher.

2. Create a catcher box by gluing together a small rectangular box.

3. Attach the box below the 3 inch slot.

4. As an **extension** activity, have the students design and laser cut their own box for a ball catcher.

Placing obstacles on the playing field/decorating the pinball machine

1. Choose objects to place on the playing field to make obstacles for the marble as it travels on the playing field.
2. Carefully decide on the layout; make sure that the marble will not get stuck on an obstacle.
3. Use hot glue to attach obstacles.
4. Paint or decorate the pinball machine to match a theme if you have chosen one.

Step Eight

Step Eight: FINAL PRESENTATION

1. Students present their pinball machines to the class.
2. Students complete reflective memo for the project. (uploaded to folder)

Teacher Led Discussion: Teacher will discuss levers and inclined planes, which are two of the simple machines. In most cases simple machines are used to make our lives easier by requiring a smaller input force to get a larger output force. In the case of the flipper, we sacrifice the force advantage to gain a larger range of motion.

The inclined plane is the playing field of the pinball machine. By having an angle we increase the speed of the marble as it goes down the incline toward the flipper. This makes the game more

exciting and challenging.

Outcomes

Essential Questions:

- How can you calculate power?
- How can you calculate a joule?
- How are work and kinetic energy of a moving object related?
- In what ways can energy be effectively conserved?
- How do machines use energy to do work?
- How are work, power, and energy related?
- When is work done on an object?
- What are two forms of mechanical energy?
- How does a machine use energy?
- Why can't a machine be 100% efficient?

Essential Digital Fabrication Questions:

- How do you document your design and fabrication process?
- How do the dimensions of raw materials impact your design?
- How do the limitations of your digital fabrication machine impact your design?
- How do you design individual components on a computer?
- How will your individual components be assembled to create a full pinball machine?
- What changes did you have to make to your initial design to improve your pinball machine?
- How do you operate the laser cutter?
- How do you use hand tools to finish your pinball machine?
- How will you share your final pinball machine with the rest of the world?

Student Assessments

Students' knowledge, skills, and aptitudes will be assessed using selected response items and rubrics for class participation, group work, engineering problem solving, brief constructed responses, and extended constructed responses summarizing the lesson.

Pre-Test Practice Test (Chapter 9- with answers)
http://marsd.org/cms/lib7/NJ01000603/Centricity/Domain/266/CD%209.1%20Work%20and%20Energy%20Answers.pdf

Formative Assessment (Chapter 9-with answers)
https://d3jc3ahdjad7x7.cloudfront.net/YhXdaDN05u8IzfPKjlMqrJ7KQZJlSEgbGQLCfrwLSx3xNDo6.pdf

Post-Test (Repeat of Practice Test)
http://marsd.org/cms/lib7/NJ01000603/Centricity/Domain/266/CD%209.1%20Work%20and%20Energy%20Answers.pdf

Pinball Machine Student Project Rubric[2]

The Pinball Machine student project rubrics will be presented in advance of the activities to familiarize students with the expectations and performance digital fabrication criteria. They will also be reviewed during the activities to guide students in the completion of assignments.

Design Specifications **27 pts (3pts each)**
Sturdy sides to keep ball in field
Ball launcher mechanism
Buttons to activate the flipper are easily pressed
Flipper mechanism made of 4 layers of cardboard
Flipper mechanism easily pivots
Obstacles in playing field
Ball catcher
Ball does not get hung on playing field
Barriers that keep the ball from going behind flippers

Explanation *(must be neatly written on a separate sheet of paper)* **24 pts (4pts each)**
Explanation of how levers are used in your pinball game
Explanation of how elastic potential energy is used in your pinball game

Analysis
a. Measure distance between where the button attaches to the flipper and pivot: _____
b. Measure distance between where the marble hits the flipper and pivot: _____
c. Find the force multiplier ratio (b divided by a): _____
d. Measure the angle of your playing field: _____

Documentation **28 pts (4pts each)**
Original Sketch
Final Sketch Side view
Final Sketch Top view
Neatly drawn
Picture or Sketch of Flipper Prototype
Sketch of Ball Launcher Mechanism
Picture of Final Pinball Machine

Aesthetics **10 pts**
Neat Construction
Interesting decorations

Other
Group evaluation 8 pts(uploaded to folder
Self Evaluation 3 pts

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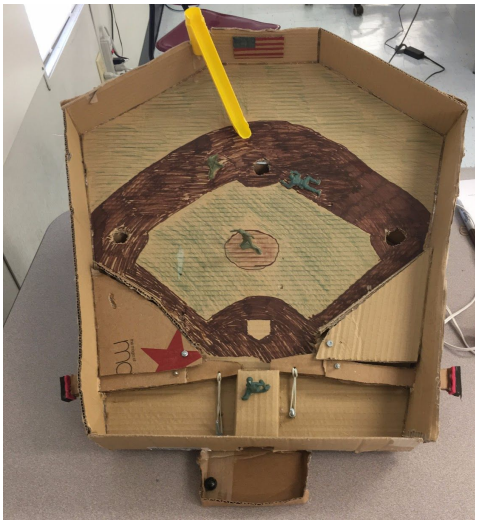
[2] NOTE: This is Teresa's Original Rubric for her Pinball Machine Lesson

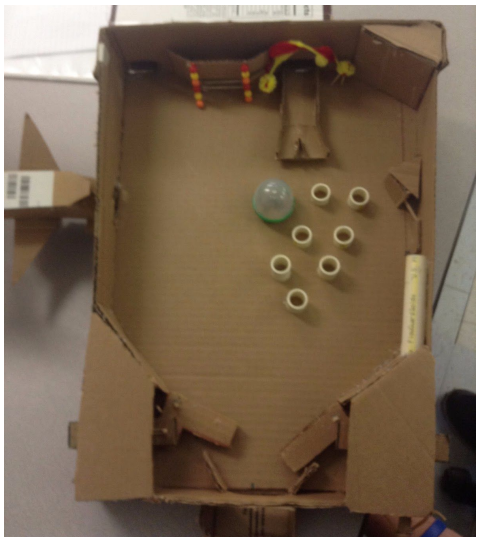
Bonus Points for Theme 10 pts

Finished Student Project Examples

Example Pictures of Pinball Machines and Planning Boards

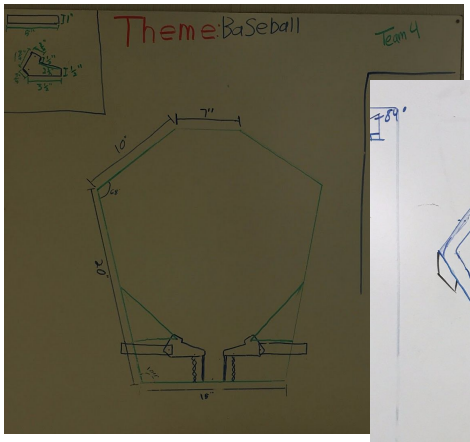


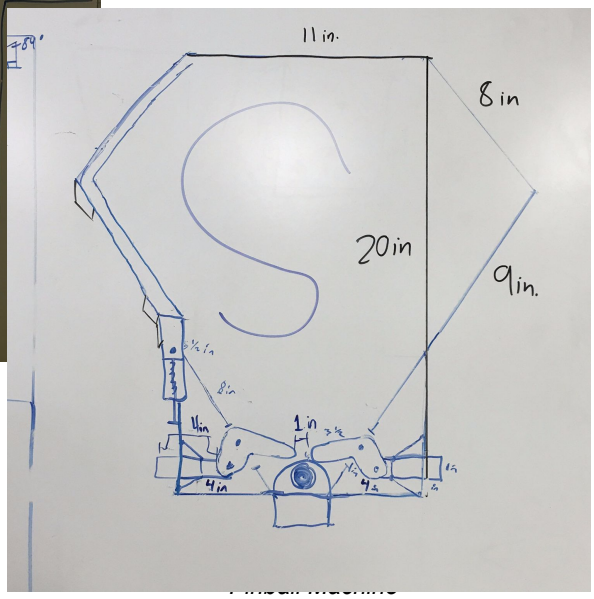
Notice the yellow ramp on the top of this picture. This is an alternative method of ball launch. The ball is placed at the top of the ramp to launch.



In this example, the ball launcher is inside the base of the pinball machine.

These are examples of the planning boards students used to create pinball machines.





More Resources:

More videos:
https://www.youtube.com/watch?v=gnrrbKFWL3Q
https://www.youtube.com/watch?v=1EN3pkeID1Y
https://www.youtube.com/watch?v=jqwOaPYjKXI

Bell Crank
https://www.youtube.com/watch?v=-nuAhMMAbXw
https://www.youtube.com/watch?v=26D-_Fo0TIk

More posts from Teresa on Twitter: https://twitter.com/tbsappington/status/829772980586737665

Standards

Next Generation Science Standards Understandings:

- Energy cannot be created or destroyed, but only changed from one form into another.
- Mechanical energy can be considered either to be kinetic energy, which is energy in motion, or potential energy, which depends on relative position.
- Energy exists in many forms, and when these forms change, energy is conserved.

Next Generation Cross-Cutting Concepts[3]:

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- The total amount of energy and matter in closed systems is conserved.
- Energy drives the cycling of matter within and between systems.
- Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Common Core English Language Arts/Science & Technical Subjects Standards:

- 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

[3] Adapted from National Research Council (2011), A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Idea. (Chapter 4: Crosscutting Concepts).

text.

- RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

- RST.9-10.5. Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).

- RST.9-10.8. Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

- RST.9-10.9. Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Common Core Mathematics Standards:

- HSN.Q.A.1: Use units as a way of understanding problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

- HSN.Q.A.2.: Define appropriate quantities for the purpose of descriptive modeling.

- HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurements when reporting quantities.

- HSN.CED.A.2: Create equations in two or more variables to represent relationship between quantities; graph equations on coordinate axes with labels and scales.

Digital Fabrication Competencies: I Can Statements

- (S.2) *Safety*: I can operate equipment in a Fab Lab following safety protocols.
- (DP.2) *Design Process*: I can design something in a Fab Lab using a specific process under close instructor guidance.
- (DP.3) *Design Process*: I can create analog models (e.g. sketches, small physical models, etc.) to facilitate a design process.
- (DP.4) *Design Process*: I can record and share my ideas during a design process to document the learning process (e.g. journal writing, group reviews, etc.).
- (DP.5) *Design Process*: I can work with a group to follow multiple common design process steps (e.g. defining the user, brainstorming, prototyping, iterating, etc.).
- (CAD.2) *Computer Aided Design*: I can draw a basic design using 2D Vector graphics.
- (CAD.6) *Computer Aided Design*: I can design a 3D component using 2D design software (e.g. press-fit or folded components).
- (MO.2) *Machine Operation*: I can safely operate a digital fabrication machine under close observation of an instructor.
- (F.3) *Fabrication*: I can modify pre-designed components and subsequently fabricate the components using one digital fabrication process.
- (SC.1) *Sustainability and Commerce*: I use scrap and renewable resources like cardboard first, before

using higher cost materials. I understand the cost of various raw materials in the Fab Lab.
- (CT.2) *Critical Thinking*: I can identify the design problem, investigation, or challenge.
- (Q.2) *Questioning*: I can formulate questions that reveal important aspects of design process including problems and challenges.
- (PS.3) *Proposed Solution*: I can propose alternative solutions to a design problem through iterations and determine their utility through execution.

Differentiated Instruction

The teacher may incorporate accommodations/modifications of IEP such as extended time, oral presentation, and scaffold learning. Example is the used of ***QUIZLET Flashcard on Energy*** https://quizlet.com/31988791/conceptual-physics-chapter-9-energy-flash-cards/

Enrichment students can do self-directed learning using Khan Academy. ***Introduction to Work and Energy*** https://www.khanacademy.org/science/physics/work-and-energy/work-and-energy-tutorial/a/what-is-gravitational-potential-energy

Optional Next Generation Science Standards (Physics A) for enrichment students including:

- **Physics A: HS - PS2 - 1**. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- **HS - PS2 - 2**. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
- **HS - PS2 - 3**. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimize s the force on a macroscopic object during a collision.
- **HS - PS2 - 4**. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
- **HS - PS3 - 1**. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- **HS - PS3 - 2**. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.
- **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.

Instructional Time: At least 2 hours are required for this lesson. However, time could vary significantly depending on the equipment available in your classroom and capabilities of the students.

Classroom Reading Material

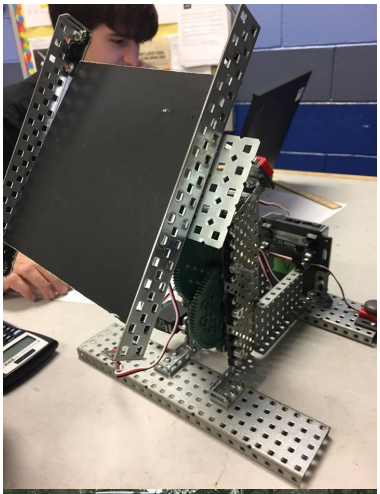
Conceptual Physics Textbook**. Chapter 9 (Energy-Teacher Version)**
http://www.athenscsd.org/userfiles/55/Classes/790/userfiles/55/my%20files/ch9-energy-cp.pdf?id=5101

Contributor Profile

Name: Teresa Sappington
Role: Teacher
Organization: Lamar County Technical Center
Location (City, State, Country): Purvis, MS

Contact Information
Email: teresa.sappington@lamarcountyschools.org
Phone: (601) 466-2774

Bio: Teresa teaches high school engineering, 3D Computer Aided Design (CAD) and VEX robotics at the Lamar County Center for Technical Education (LCCTE). She served as an Albert Einstein Distinguished Educator Fellow (AEF) in the US House of Representatives and in the Congressional Maker Caucus. She previously taught physics, Chemistry, Engineering, and Research at Oak Grove High School in Hattiesburg, Mississippi. While there, she spearheaded the addition of Introduction to Engineering into the school's curriculum. Teresa earned a Masters in Science Education and a Bachelors in Chemistry-Physics Education from Mississippi State University. Sappington achieved National Board Certification in 2008.



Organization: The Lamar County Center for Technical Education in Purvis, Mississippi provides technical and career classes for students from Lumberton High School, Oak Grove High School, Purvis High School, and Sumrall High School. At LCCTE, teachers and staff offer a unique experience to engage students in a variety of programs, combining academic and technical skills, while preparing them for opportunities beyond high school. Whether students are college bound or ready to start their careers, CTE programs offer a combination of academic rigor, technical skill development, and the soft skills that will set them apart in both college and the workplace.

About SCOPES-DF

Fab Foundation's new SCOPES-DF (Scaling a Community of Practice for Education in STEM through Digital Fabrication) project aims to catalyze STEM learning in formal educational environments through digital fabrication technologies and practices found in a Fab Lab or makerspace. Our goal is to build a community of in and out of school K-12 practitioners by co-curating and openly sharing digital fabrication lessons that are aligned to standards, and engaging for students and teachers. This lesson was based on one of over 50 submissions in the first round in June 2017 to be aligned to educational standards, reviewed by educators, tested with youth and educators in Fab Labs, and standardized into a common "Fab Tested" collection to seed the future online community of practice at SCOPESDF.org.

The Fab Foundation is a U S based non profit formed to facilitate and support the growth of the international fab lab network. The Fab Foundation has three programmatic foci: education, capacity building and services, and business opportunity. For more information about the Fab Foundation visit **www.fabfoundation.org**

Join Us!

To sign-up for early access or submit an activity, project or lesson in the interim, visit **http://scopesdf.org/get_ involved**.

Email **scopesdf@fabfoundation.org** to volunteer to test these lessons with your students.

FABFOUNDATION Chevron GE Foundation

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