Energy Transfer Machine

Student Objectives
The student:
- understands the law of conservation of energy
- will explain the energy transfers in their machine
- will explain how simple machines work together to create larger complex machinery
- will use the engineering design process to complete a task
- will work on a team to design, build, test, troubleshoot, modify and complete a "Rube Goldberg" type machine.

Key Words:
chain reaction
conservation of energy
contraption
convoluted
energy transfer

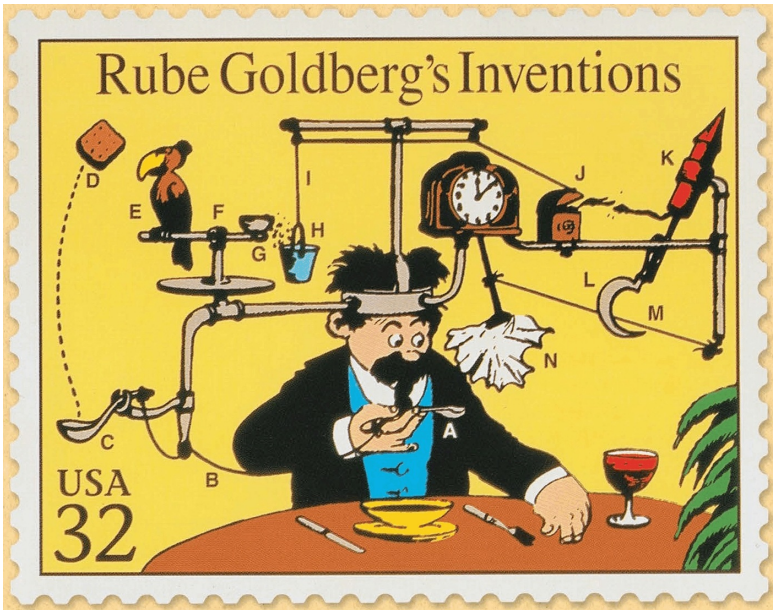
Time:
Varies (at your discretion) – 2 hours to several weeks

Materials:
- Various objects to use in contraptions (see Building Materials idea list)
- Theme and odd "confounding" items in paper bags, at least one bag of each per group (see Building Materials idea list)
- Construction equipment such as scissors, hot glue gun, duct tape, masking tape, clear tape, twine, zip ties, wire, cardboard boxes
- Odd or silly (Rube Goldberg-ish) small objects or stickers as "trophies" for the winning team

Background Information

Rube Goldberg machines get their name from Rube Goldberg, an American cartoonist, sculptor, author, engineer and inventor who became famous for his cartoons in the early 20th century. A Rube Goldberg machine does a relatively simple task in a convoluted, overly complex, and usually humorous way. In one of Rube Goldberg's cartoons that was used for a U.S. postage stamp, he shows a Self-Operating Napkin that takes 14 steps and utilizes among

other things, a parrot, a clock and a firecracker.



Goldberg's explanation of his Self-Operating Napkin:

> *"As you raise spoon of soup (A) to your mouth it pulls string (B), thereby jerking ladle (C) which throws cracker (D) past parrot (E). Parrot jumps after cracker and perch (F) tilts, upsetting seeds (G) into pail (H). Extra weight in pail pulls cord (I) which opens and lights automatic cigar lighter (J), setting off sky-rocket (K) which causes sickle (L) to cut string (M) and allow pendulum with attached napkin to swing back and forth thereby wiping off your chin. After the meal, substitute a harmonica for the napkin and you'll be able to entertain the guests with a little music."*

Goldberg received an engineering degree from the University of California Berkeley (1904), mainly to appease his father who did not think that art was a true profession. After graduation, Rube took a job with the San Francisco City Engineer's Office, but after six months of designing sewers and water systems, he quit to take a job as a sports cartoonist. Three years later he moved to New York to work as a cartoonist for the city publications, which soon led to nationwide fame. Between 1929 and 1931 he worked on a series called "The Inventions of Professor Lucifer Gorganzola Butts" which featured labeled schematics of comical inventions that purported to accomplish a simple task in a ridiculously complex and impractical way. In later interviews he said that these were inspired by his experiences in college engineering classes, and his idea that technology which is intended to simplify people's lives can actually make them more complicated. He once described his work as "a symbol of man's capacity for exerting maximum effort to accomplish minimal results." In 1966 "Rube Golberg" was added to the Webster's Dictionary as an adjective meaning "having fantastically complicated improvised appearance," or being "deviously complex and impractical."

Rube Goldberg never built any physical contraptions, his drawings were just meant for humor. Even so, Rube Goldberg Machines as a physical manifestation and competition started in 1949 when two rival fraternities at Purdue University held a Rube Goldberg competition inspired by his cartoons where "each house contributed an infernal machine capable of doing nothing the

hard way." As those first students graduated, interest waned and the competition was forgotten until 1981 when the trophies were found in an attic. The competition was revived at the university and expanded nationwide in 1989. In 2013 the contest was moved to the COSI Science Museum in Columbus Ohio. In the current collegiate Rube Goldberg Machine Contest, teams must accomplish an assigned task (for example zip a zipper or open an umbrella) in two minutes using at least 20 steps and no more than 75 steps.

Although much of Goldberg's humor has not held up well over the decades, his idea that technology can make our lives more complicated instead of easier certainly has. In 1967 he drew a cartoon called "The Future of Home Entertainment" that shows a family in their living room with everyone including the cat watching their own screens. It seems he knew human nature pretty well.

Procedure (prior to class)

Note: This activity can be done as a classroom activity with a time limit on the machine building (recommended minimum of 2 hours), a classroom activity that encompasses several weeks, or a group activity that is done after school (or at a group member's home) and videoed for presentation to the class.

1. Write machine End Goals on slips of paper and staple shut or put into envelopes. You should have enough for one for each group and a few extras for "swap outs". Some ideas for End Goals can be found in the Building Materials section.
2. Make up paper bags with 2 - 3 "confounding" items in each one. You should have one more than the total number of groups. These bags are stuffed with odd items for the students to incorporate into their machines. Such items could be tools (for example a hammer), office supplies (stapler, eraser, cd), household items (spatula, sieve), or random objects you find in your classroom or at home (yo-yo, toy xylophone, gyroscope, bell, etc.). Almost anything can be used. Label these bags "Gizmo.".
3. Make up paper bags with 1 - 2 "Theme" items in each one. You should have one more than the total number of groups. Some ideas for themes can be found in the Building Materials section. Be creative with this–it is meant as a starting point for the students–encourage them to run with the idea they receive. Label these bags "Theme". *(Alternately, if the students are going to be working on their machines for several days, you could print theme ideas on slips of paper and task the students with finding items to use that represent this theme.)*
4. If you are building in class, set up a table with a variety of building materials and supplies.

Procedure (during class)

1. Show the class a video of a Rube Goldberg type machine. You could choose a professional one (such as OK Go!, Honda, or GoldieBox), a student created machine (such as Lily Hevesh, or Audri's Clemmons), or an overview (like the PBS Sunday Morning show). See the listings in the Internet Sites section for links and other ideas.
2. Discuss the video and some of the simple machines that were in the Rube Goldberg machine. Briefly review the six simple machines if necessary (lever, wheel & axle, inclined plane, wedge, screw, and pulley), and have the students give examples of each

from the video.

3. Show the class some examples of Rube Goldberg's original cartoons. Discuss with the class how he used humor and unusual objects. Ask the students what point they think Goldberg was trying to make with his art. Discuss briefly with the students how art and humor can be used to help people reflect about something.
4. Explain to the class that they are going to be building (in groups) a Rube Goldberg machine to perform a task.
5. Break the class into groups of 4 - 6 students per group, and have the students sit with their group. Show another video or two that demonstrates different techniques used in Rube Goldberg machines (see listings in the Internet Sites section). Encourage the students to take notes of things they like and discuss ideas within their group.
6. Explain the Energy Transfer Machine Challenge to the class (you may wish to project/post the challenge rules for the class):
    - Each team will select an end goal slip (or envelope) that will tell them what they are designing their machine to do.
    - Each team will select one Gizmo bag and one Theme bag.
    - Teams may opt out of one of the items in their Gizmo bag with no penalty.
    - Teams that wish to switch out their End Goal may swap sight unseen for another one, but they must keep that one and cannot trade back. Additionally, if they swap their end goal, they must use all of their Gizmo objects.
    - The machines must incorporate at least 5 energy transfers.
7. If the students are going to be building outside of the classroom and videotaping their machines, go over the video guidelines with the class:
    - At the beginning of the video, one or more of the team members must describe and point out the path the "action" of the machine will take, and describe the energy transfers that will occur.
    - The beginning narration can be recorded separately from run of the machine that will be presented to the class.
    - Only one "run" of the machine (your best one) is to be turned in. Don't turn in all your attempts/failures.
    - The part of the video that shows your machine in action must not be edited–it must be recorded in one continuous stream. Teams may not piece together segments from different runs.
8. If from past experiences you know that your class tends to "hoard" materials, you may also want to limit the number of items a group may take at one time from the building materials table.
9. Assist the students as needed, periodically reminding them to return materials that they decide not to use to the building materials table.
10. Students should complete their Science Journal once they have their machines built.

Procedure (presentation day)

1. At the end of the building period (whether it is 2 hours or 2 weeks) have the students present their machine (or video of their machine) to the class. If the real machine is being presented (instead of a video), before starting the machine, the teams are to describe what their machine will do, and its energy transfers.

2. Go over the Presentation Rubric with the class, and give examples things to consider. For example:
    - End Goal – Did the machine work all the way? How many times did the team have to help the machine when it was stuck?
    - Number of Energy Transfers – since five is the minimum, did the team achieve the minimum? Did the machine have more than five? The higher scores should have the most transfers.
    - Use of Theme and Gizmo Items – did the team use all of them? Were they an important part of the machine or just a decoration that didn't really add any action?
    - Machine Description – how well did the team describe their machine? Did you know what was going to happen?
    - Creativity/Humor/Entertainment – How much did you enjoy the machine? Was it fun? Did the group come up with new ideas?
3. As each group presents their machine, the other students should rate them using the Presentation Rubric, and add up each team's scores.
4. Tally the scores and declare a class winner. Award each member of the team some silly, Rube Goldberg-ish small prize or sticker.

Key Words and Definitions

- **chain reaction –** a series of events, each caused by the previous one
- **conservation of energy** – a principle stating that energy cannot be created or destroyed, but they can be transformed, each into each other
- **contraption** – a machine or device that appears strange or unnecessarily complicated, and often badly made
- **convoluted** – extremely complex, intricately folded, twisted or coiled
- **energy transfer** – the conversion of one form of energy into another or the movement of energy from one place to another
- **Rube Goldberg** – (1883 - 1970) an American cartoonist, sculptor, author, engineer, and inventor whose name has become synonymous with doing a usually simple task in a convoluted, overly complex, humorous way.

Further Research

1. Look at several Rube Goldberg cartoons on the internet or in books. Draw a Rube Goldberg type of cartoon about doing homework, getting out of bed, or something else that you do every day. Remember to make it as complex (and silly!) as possible.
2. Submit a video of your Rube Goldberg machine to the Energy Transfer Machine competition at the Florida Solar Energy Center. Information and rules for the competition can be found here: **http://www.fsec.ucf.edu/go/etm**

Related Reading

- ***Build Your Own Chain Reaction Machines: How to Make Crazy Contraptions Using Everyday Stuff–Creative Kit-Powered Projects!*** By Paul Long (Quarry Books, 2018)
  This book includes thirteen projects with step-by-step instructions for making low-tech devices using everyday objects in inspired and ingenious ways. Create machines that flip a light switch, squeeze toothpaste, dispense candy, etc.
- ***Rube Goldberg's Simple Normal Humdrum School Day*** by Jennifer George (Abrams, 2017)
  This book follows Rube as he sets out on a typical school day, over complicating each and every step from the time he wakes up in the morning until the time he goes to bed at night.

Internet sites

Note: The internet is full of Rube Goldberg sites. These are just a few of our favorites.

Introductory videos (professional)

https://www.youtube.com/watch?v=qybUFnY7Y8w
Video, *OK Go! - This Too Shall Pass*. High intensity, large two-story Rube Goldberg machine set to the band's music. Links are available to a behind the scenes look at creating the machine and an interactive map that details the components.

https://www.youtube.com/watch?v=YWk9N92-wvg
Honda commercial features a Rube Goldberg machine made exclusively out of Honda car parts.

https://www.youtube.com/watch?v=V4BuUnimp8s
GoldieBlox Rube Goldberg Princess Machine. Video commercial for GoldiBlox shows three girls and the Rube Goldberg machine they supposedly built.

Introductory videos (student created)

https://www.youtube.com/watch?v=VdSSOAtIrYU
Fortune Telling Machine, Lily Hevesh, internet domino artist, builds a machine to open a fortune cookie. In a second video, **https://youtu.be/VdSSOAtIrYU**, Lily gives a behind the scenes look at how she constructed the machine and the problems that she encountered. This video includes good advice for builders.

https://www.youtube.com/watch?v=IMboI4cOAuQ
Audri's Monster Trap. Seven year old, Audri Clemmons, shares his Rube Goldberg machine to trap a monster. He explains how his machine should work, shares some failures and his final success in trapping his stuffed monster under a colander.

Introductory videos (overview and history)

https://www.youtube.com/watch?v=40AO2RdEixs
CBS Sunday Morning video report on Rube Goldberg and the Rube Goldberg machine competition. This short video is good for introducing the concept to class.

https://www.pbs.org/video/rube-goldberg-a-lot-of-moving-pieces-1708-78hysj/
PBS Newsmakers video, *Rube Goldberg: A Lot of Moving Pieces*. This PBS video is a

longer video that is good for older or more advanced (or art) students as an introduction of the art behind Rube Goldberg cartoons.

Videos to spark ideas

https://www.youtube.com/watch?v=cv5WLLYo-fk

75 Chain Reaction Ideas & Inventions includes some great ideas including some big, showy ideas. Don't be fooled, however, the different parts were recorded separately and then pieced together. See if your students spot this!

https://www.youtube.com/watch?v=MrbDg_aO1LQ

Video, Insanity Kontraption where a physics class turns off their light, using the whole classroom in the process.

https://www.youtube.com/watch?v=TdTYXc9EYHo

Andrew's second grade Rube Goldberg machine to pop a balloon. It includes his explanation and discussion of his favorite parts, as well as 3 different camera views of the machine run.

https://www.youtube.com/watch?v=Wfw8IyRTWUw

Student made video of a Rube Goldberg machine to wake a younger brother.

https://www.youtube.com/watch?v=Spxq_3Ei6uM

Steve Price's Rube Goldberg machine that flattens a can. This video was made when Price (now professionally know as Sprice) was a student. He went on to become a professional Rube Goldberg machine designer. He has many other videos online that are full of fun ideas.

https://www.youtube.com/watch?v=PxIZPNhO-z0

National Geographic video. Two teams build Rube Goldberg machines using the same objects. The video shows how to work as a team and work backwards to reach the goal of trapping a stuffed mouse.

Other Websites

http://www.fsec.ucf.edu/go/etm

Florida Solar Energy Center, Energy Transfer Video Machine competition.

http://jiwismachines.com/

Jiwi's Machines is a website produced by Joseph Herscher, that includes four episodes of Jiwi's Rube Goldberg machines plus Science Extras that include more detailed information on forces involved and parts used in his Rube Goldberg machines. Herscher also posts student created videos on his Facebook page, **https://www.facebook.com/josephsmachines/**

Energy Transfer Machine

Note: Almost anything in your classroom or Maker's Space can be used in Rube Goldberg Machines. You may want to encourage your students to bring items from home. Also, many teachers have had luck amassing materials, especially those there are never enough of (cardboard tubes, balls, and dominoes) by requesting contributions from parents and other teachers.

Building Materials Ideas

Note: You may want to divide some desirable items (like dominoes) into several separate plastic bags so that one team cannot claim all of them!

balls and round objects of all kinds (tennis, golf, marbles, ping pong, oranges, etc.)
dominoes
blocks
popsicle sticks, tongue depressors
balloons
small vehicles (matchbox, hot wheels, etc.)
paper cups, bowls, plates, plastic spoons
track from race car sets
clothespins, binder clips, paper clips
cardboard tubes (paper towels, gift wrap)
magnets
spools
pipe cleaners, wire, twist-ties
rubber bands
wheels
books
cans
modeling clay
straws, coffee stirs
cardboard
funnels
Lego bricks, tinker toys, K-nex, etc.
clear tubing (large enough for a marble to roll through)
pulleys
rolls of tape
gears
plastic bottles (cut off tops can be used as funnels)
aluminum foil
slinky, yo-yo
rulers
wooden dowels, pencils, chopsticks
twine, rope
sand
small heavy objects (coins, nuts, bolts, etc)
chain
springs, elastic
mousetrap
Alka Seltzer® tablets, baking soda

"End Goal" Ideas

Ring a bell
Staple a paper
Crush a grape
Raise a flag
Pop a balloon
Inflate a balloon
Water a plant
Roll a car into a cup
Put a ball in a cup
Trap a small stuffed animal
Turn a page in a book
Pull a tissue out of the box
Crush a can
Shut off an alarm clock
Pour a bowl of cereal
Pour a glass of water
Put a party hat on a stuffed animal
Plant seeds in a pot of soil

Theme Bag Ideas

Note: Any items that can be loosely related will work. It is best to pick non-breakable, non-precious items. Have fun with theme items–humor is the goal.

Superheros - figurines and various other superhero merchandise
Gardening - flower pot, trowel, watering can
Carpenter - hammer, nail, screwdriver, clamp, plier
Musical - cds, harmonica, toddler instrument (unbreakable!),
Literary - typewriter (or computer keyboard), pencils, small books
Summer - sand toys, pool toys, beach ball
Breakfast - cereal box, bowl, spoon
Disney - collectible figurines and other Disney merchandise
Fruit - orange, lime, lemon, banana
Holiday - various items from the next holiday
School - various items from around your classroom
Game time - board game board, pieces, play money
Movie time - DVDs, bag of (unpopped) popcorn, soda cans

Energy Transfer Machine

Challenge Rules

Each team:

- Picks one End Goal
- Picks one Gizmo bag
- Picks one Theme bag

Your machine must use at least 5 energy transfers. A row of repeating transfers (like a row of dominoes falling into each other) counts as "1".

Teams may choose not to use one of their Gizmo items without penalty, unless they want to trade out their End Goal (see next rule)

Teams may trade their End Goal, if they wish, for one that has not been opened, but they must use the new one, and then they must use all their Gizmo items.

All machines will be scored by the rest of the class.

Presentation Rubric

Score each group's machine on a 1 - 5 scale (with 5 being the highest) for each category below. Total each group's score across.

Group # / Name	End Goal – Success?	Number of Energy Transfers	Use of Theme & Gizmo Items	Machine Description	Creativity? Humor? Entertaining?	Total

Energy Transfer Machine

Florida NGSS Standards & Related Subject Common Core

			.1	.2	.3	.4	.5	.6	.7	.8
Grade 3										
Forms of Energy	**Big Idea 10**	**SC.3.P.10**	**X**	**X**						
Grade 4										
Forms of Energy	**Big Idea 10**	**SC.4.P.10**	**X**	**X**						
Motion of Objects	**Big Idea 12**	**SC.4.P.12**	**X**	**X**						
Grade 5										
Forms of Energy	**Big Idea 10**	**SC.5.P.10**		**X**						
Forces and Changes in Motion	**Big Idea 13**	**SC.5.P.13**	**X**	**X**	**X**	**X**				
Visual Arts Standards	**Third Grade: VA.3.C.1.2** **Fourth Grade: VA.4.C.1.2, VA.4.H.1.1** **Fifth Grade: VA.5.H.1.1, VA.5.F.2.3**									

Third Grade Benchmarks

Science–Big Idea 10: Forms of Energy

- SC.3.P.10.1 - Identify some basic forms of energy such as light, heat, sound, electrical, and mechanical.
- SC.3.P.10.2 - Recognize that energy has the ability to cause motion or create change.

Visual Arts - Critical Thinking and Reflection

- VA.3.C.1.2 - Reflect on and interpret works of art, using observation skills, prior knowledge, and experience.

Fourth Grade Benchmarks

Science–Big Idea 10: Forms of Energy

- SC.4.P.10.1 - Observe and describe some basic forms of energy, including light, heat, sound, electrical, and the energy of motion.
- SC.4.P.10.2 - Investigate and describe that energy has the ability to cause motion or create change.

Science–Big Idea 12: Motion of Objects

- SC.4.P.12.1 - Recognize that an object in motion always changes its position and may change its direction.
- SC.4.P.12.2 - Investigate and describe that the speed of an object is determined by the

distance it travels in a unit of time and that objects can move at different speeds.

Visual Arts - Critical Thinking and Reflection

- VA.4.C.1.2 - Describe observations and apply prior knowledge to interpret visual information and reflect on works of art.

Visual Arts - Historical and Global Connections

- VA.4.H.1.1 - Identify historical and cultural influences that have inspired artists to produce works of art.

Visual Arts - Innovation, Technology, and the Future

- VA.4.F.2.1 - Discuss how artists and designers have made an impact on the community.

Fifth Grade Benchmarks

Science–Big Idea 10: Forms of Energy

- SC.5.P.10.2 - Investigate and explain that energy has the ability to cause motion or create change.

Science–Big Idea 13: Forces and Changes in Motion

- SC.5.P.13.1 - Identify familiar forces that cause objects to move, such as pushes or pulls, including gravity acting on falling objects.
- SC.5.P.13.2 - Investigate and describe that the greater the force applied to it, the greater the change in motion of a given object.
- SC.5.P.13.3 - Investigate and describe that the more mass an object has, the less effect a given force will have on the object's motion.
- SC.5.P.13.4 - Investigate and explain that when a force is applied to an object but it does not move, it is because another opposing force is being applied by something in the environment so that the forces are balanced.

Visual Arts - Historical and Global Connections

- VA.5.H.1.1 - Examine historical and cultural influences that inspire artists and their work.

Visual Arts - Innovation, Technology, and the Future

- VA.5.F.2.3 - Discuss contributions that artists make to society.

National Next Generation Science Standards

Third Grade Standards

Science–Engineering Design

- 3-5-ETS1-1 - Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2 - Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3 - Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Fourth Grade Standards

Science–Energy

- 4-PS3-3 - Ask questions and predict outcomes about the changes in energy that occur when objects collide.
- 4-PS3-4 - Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Science–Engineering Design

- 3-5-ETS1-1 - Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
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Fifth Grade Standards

Science–Engineering Design

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Energy Transfer Machine

1. What is the End Goal of your machine? _____

_____

2. How many transfers does your machine have? (Remember, something that repeats, like a row of dominoes falling, counts as "1" transfer) _____

3. List your energy transfers (in the order that they occur) below:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Continue on the back if you need more space.