Soft Robots

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Subject: Physics, Earth Science, Engineering

Grade Level: 9-12

Standards:

Next Generation:

Physics

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.

HS-PS3-2 Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Earth Science

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Engineering

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Schedule:

CCMR Lending Library Connected Activities:

Objectives: Students should learn how to use the Engineering Design Cycle to design, evaluate and redesign a technological solution to a specific problem by breaking it down into steps. Students will learn that understanding and properly using the correct materials is an important part of that process. Students will also learn understanding scientific phenomena is vital as well in order to accomplish and engineering goal.	**Vocabulary:** Students will learn this vocabulary during this lesson. A vocabulary guide with defintions of these words are included in the lesson packet. polymer viscosity elasticity viscoelasticity pneumatic pressure kinetic energy potential energy Bernoulli's Principle actuator robot Engineering Design Cyle energy work
Students Will: Learn about soft robotics and model the design, building and testing of one or more models. Students will follow the Engineering Design Cycle and plan for either improvements of their current robot or design and create a new version of a soft robot which relates to what they learned in the construction and testing of their first robot. The teacher will provide instructions and materials for the initial robotic design. Students will be given resources to research that will help them make an improved design of their soft robot and for its construction. Students will listen to the lecture (or read it online), view videos and read texts related to Soft Robotics and the engineering	**Materials:** Required Materials: Cardboard (about two square feet) Box Cutter Cutting Board Hot Glue Gun Scotch Tape Smooth On Ecoflex 00-30 Scissors Printer paper Nail Soda/water bottle with lid (at least one liter) 1/8 in OD pneumatic tubing Curling ribbon

problems that they are trying to solve. Students will take Cornell notes on the assigned readings and include the vocabulary words listed. Students will incorporate relevant information in their Scientific Report from the articles and cite the reference. Students may alternatively prepare a powerpoint, video, or poster as a Scientific Report. Students may also do additional research in support of their project.	
Safety	Eco Flex 30 and 50 are silicone rubbers that has been tested and found safe for use as prosthetic devices. Most people will not have an allergic reaction to it. If this does occur, the students may choose to handle the robot with gloves. Eco Flex 30 and 50 do not have to be used under a hood. Students should be careful with the hot glue and glue gun so that they do not burn themselves. The teacher may choose to use a "cool" glue gun.

Content for the Teacher:

Readings and Resources are also helpful for students.

Human Sustainability and Soft Robotics

Next Generation Content Standards for Earth Science states that "By the end of

grade 12 a student should understand: "The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. Scientists and engineers can make major contributions—for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. When the source of an environmental problem is understood and international agreement can be reached, human activities can be regulated to mitigate global impacts (e.g., acid rain and the ozone hole near Antarctica).

The sustainability of human societies and of the biodiversity that supports them requires responsible management of natural resources not only to reduce existing adverse impacts but also to prevent such impacts to the extent possible. Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation."

Food Handling and packaging relies significantly on manual labor. In some cases, low cost migrant labor has been used for this work. However, the pools of workers available for low income, manual labor are uncertain as is access to migrant workers. The expense of manual labor and the lack of reliable and consistent sources for these workers impacts the effort of food producers to be economically viable. Manufacturers are turning to automation to maintain productivity. Traditional robotics does not work well for food handling and packaging. What is needed are robots that have something more like a human hand. In fact the US government cites "flexible gripping mechanisms that allow for dexterous manipulation of everyday objects" as a national imperative in its "2016 Roadmap for Robotics report".

The problem is not limited to food handling. The population is our country is aging and robotics may provide solutions for the future care of geriatric or disabled individuals. Traditional robots have rigid linkages and are not well equipped to safely interact with humans. Robotic surgical machines have shown that in at least one venue, robotics can help to provide medical care. However, there are many different kinds of touching and handling needed to provide medical and custodian care and soft robotics are better suited for some of these.

Outside of the automotive industry, only about 12% of existing industries are automated by robots. Global food demand is expected to rise between 59% to 98% by 2050. Human workers are not providing enough labor. For instance, between 2002 and 2014 California lost about $3 billion in revenue because of farm worker labor shortages.

The use of soft robotics may provide a solution for unmet labor needs. Current type of robots with hard linkages cannot be used for many of these jobs. Soft Robotics can positively impact the availability of food as well as provide for work to safely process and package the food.

Soft robotics may help humankind feed its expanding population as well as care for the aging and disabled.

Momentum and Collision

The study of collisions is a fundamental topic in science. Collisions are part of the broader physics domain of mechanics.

Momentum is defined as the product of a particles's mass times its velocity. The more massive an object, the more momentum is associated with it. A suddent change in momentum results in an impulse. One example of an impulse is a car crash. The damaging effects of a collison is to extend the time of of the impact by using a cushioning material. In the case of a car crash, the force of the impact is reduced by extending the time over which the person is in the crash before they stop completely. A crumple zone in the front of the car works the same way. Softer materials in the front of a car crumple in a collision and extend the time that the car is in the collision. In the case of protecting the person directly in a car crash, an air bag acts as a cushion material. When the softer materials in the front of a car crumple during a car crash, the actual softer materials in the front part of the car body are acting as a cushioning material.

In thinking of a way to solve the problem of a soft robotic gripper that will not damage fragile items which it handles is to consider the motion of the cripper grabbing an object as a collision. The inflation of the robotic body and its construction out of soft polymers create a cushioning effect so that the objects being handled are touched with a softer impact.

https://sustainableamerica.org/blog/how-to-make-the-food-system-more-energy-efficient/

https://www.chooseenergy.com/blog/energy-101/energy-food-production/

https://www.shmoop.com/energy-momentum/work.html

Polymers and the Elastic Modulas.

Polymers are made up of many many molecules strung together to form long chains. The properties of things made from polymers are related to the molecular structure of the polymers, how the atoms and molecules are connected, and which kinds of atoms and molecules make up the substance. Viscosity and elasticity are two properties which result in variation in the performance of a polymer material. The higher the viscosity of a fluid, the more resistent it will be to deformation from sheer or tensil stress. High viscosity materials not only resist deformation, but once they deformed, they will not return back to the shape they held before the deformity.

Viscoelastic materials have elements of both viscous and elastic materials. **Elastic** materials have crystalline ordered structure and so the bonds will stretch in an ordered way. Materials with higher viscosity have atoms and molecules diffused in an amorphous (not connected in crystalline structure) structured.

An **elastic modulus** is a quantity that measures an object or substances resisistance to being deformed elastically. Something that is being deformed elastically will return to its original shape after the force deforming it is removed. For instance, a rubber band when it is being stressed will return to its relaxed state when it is no longer being streatched. A material with a high elastic modulus will be stiffer.

The Soft Robotic Lesson Plan introduces and models several “big ideas” from the Next Generation Science Standards. The links that are included with this lesson plan are meant for the students to read or view. The student should take notes on the resources in their science notebooks. Cornell notes are are good format to use and a link for Cornell notes are included.

The lesson plan is meant as a conceptual introduction to these concepts. Research based methods for teaching physics concepts have indicated that it is very helpful for students to first model and observe concepts working before they start on working problems with formulas and computations. Additionally, some school districts are actually requiring that the first physics class a student take be conceptual only. In that case, the students may opt to take an AP Physics class that includes formulas and computations.

The construction of the robot gives students the opportunity to practice the Engineering Design Process. The students will follow a specific design for their first robot, but will design and make improvements to their first robot based upon their own testing and evaluation of it. The students may either improve the first robot they made or design, make and test another. Some educational research indicates that students may learn better from physics labs in which they have some leeway to explore and create in the process of discovery. This lesson plan is designed to attempt to provide students with this kind of learning experience.

Students will be given links to other soft robotics designs that do not require a 3D Printer. Students can do their own research as well. After two robots (or one robot and a redesign of it) are constructed and tested, the student will write a Scientific report on the project. The students may do a written report, a video, a powerpoint or a poster.

As an extension of this assignment for an Earth Science Class, the students can do a short research paper on how soft robotics can positively affect food production and processing and how this might impact the human sustainibility issue of needing to feel an ever-increasing global population. Students should use the proper style for a scientific report and also include citations. A link to the Purdue Owl is included to help the students understand the proper format. The teacher may choose to have a class lesson on the style and proper format for a scientific report. Some suggested links to follow are included. If the teacher has access to a 3D printer, there are resources which include downloadable files and instructions for making a soft robot using a 3D printer

Construction of the Robot

Engineers and scientists have recently been doing a great deal of work with a kind of robotics called “Soft Robotics”. Soft Robotics are often made of polymers such as silicone rubber or others so that will have more “give” when they must handle and grip more delicate and irregularly shaped objects such as food and people.

Some soft robots are created from molds made with a 3D printer. This classroom activity includes a plan that allows students and teachers without a 3D printer to model and experiment with a construction similiar to that used by soft robotics designers. The students will make a mold for the robot by hand using cardboard, scotch tape and a hot glue gun. They will use paper within one piece of the body within the latex to make it a bit stiffer than the other piece.

The soft robot that is created in this lesson plan moves as the air in a squeeze bottle “power source” moves from the bottle through a tubing and into the flexible and hollow robotic body. We are emulating the soft robots which are being created to grip irregularly shaped and fragile objects without harming them. Our soft robot does not have a computer central processing unit translating the input to an output. Because this is a low tech and inexpensively created pneumatically powered soft robot, we are not using a computer program to guide the robot and move the actuator. The actuator instead moves due to the squeeze bottle being pressured and the air flowing from the squeeze bottle through the tubing and into the robotic body. However, since we are simply allowing the students the opportunity to model and observe how a soft robot gripper works, perhaps the human brain could fill in for the Central Processing Unit. In its simplest form a robot is defined as an input to a Central Processing Unit and a resulting output. In the case of our soft robot, the output is the movement of the robot body or actuator when the pressured air flows from the bottle to the robot.

After being molded and cured, the robotic parts are then hot glued together to make a hollow robot body. The process of gluing a bottom on the robot that is made of material that is stiffer than the other part emulates a process used by some robotics designers to combine two kinds of materials with different degrees of elasticity together. A squeeze bottle is used as the power source for the robotic actuator. An actuator is a device that moves. A piece of tubing connects the squeeze bottle to the actuator. Ribbon is then wrapped around the body of the actuator to contrain the flexibility in a way that improves function. The Robot will be made out of two parts, a top and a bottom. The parts that are molded are a long retangular box (the body) and a bottom kind of lid that is thinner. A video link to video instructions to make the first soft robot are included. The instructions are also summarized here. The students will later improve upon their robot or design and create a new one after testing the first one. Some links to other soft robot designs that do not need a 3D printer are included. The students can also research and plan their own new design as well. Many resources are available online with more ideas for soft robotic construction and experimentation.

The link with video instruction is included here. The instructions are also summarized on this work sheet.

Video Instructions for DIY Soft Robotic Gripper:

https://www.youtube.com/watch?v=uPx8x...

http://writing.engr.psu.edu/workbooks/designreport.html

This is a good outline of how the Engineering Design Cycle works. The work we did in this class in designing, building testing and redesigning the soft robot is an example of the Engineering Design Cycle.

https://www.teachengineering.org/activities/view/cub_creative_activity1

Additional articles assigned to the student follow:

Potential and Kinetic Energy
http://www.physicsclassroom.com/class/energy/Lesson-1/Potential-Energy
Work, Energy and Power
https://www.shmoop.com/energy-momentum/work.html
Viscoelasticity
https://www.teachengineering.org/lessons/view/cub_surg_lesson04
Pneumatics
https://www.explainthatstuff.com/pneumatics.html

Soft Robotics
https://orl.mae.cornell.edu/

https://softroboticstoolkit.com/

https://www.weforum.org/agenda/2018/06/robot-soft-hands-sustainable-production-soft-robotics/

Students will take notes on this vocabulary in their science notebooks.

Soft Robotics Vocabulary List

Polymers are made up of many many molecules all strung together to form really long chains (and sometimes more complicated structures, too).
What makes polymers so fun is that how they act depends on what kinds of molecules they're made up of and how they're put together. The *properties* of anything made out of polymers really reflect what's going on at the ultra-tiny (molecular) level. So, things that are made of polymers look, feel, and act depending on how their atoms and molecules are connected, as well as which ones we use to begin with! Some are rubbery, like a bouncy ball, some are sticky and gooey, and some are hard and tough, like a skateboard.

Viscosity of a fluid is the measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal concept of "thickness": for example, honey has a higher viscosity than water.\

Elasticity is ability of a deformed material body to return to its original shape and size when the forces causing the deformation are removed. A body with this ability is said to behave (or respond) elastically.

Viscoelasticity is the property of materials that demonstrate both viscous and elastic characteristics when undergoing deformation from a stress. Viscous materials like water resist shear flow and strain with time as a stress is applied. Elastic material strain when stretched and immediately return to their original shape once stress is removed Viscoelastic materials have elements of both and also exhibit time-dependent strain. Elasticity usually happens because bonds stretch in an ordered way across crystallographic planes in an ordered solid. Viscosity usually happens because of the diffusion of atomes or molecules inside an amorphous (not crystalline ordered) solid.

Pneumatics is a branch of engineering that uses gas or pressurized air. Pneumatic systems transfer energy from the potential energy of the pressurized gas into the kinetics of moving an actuator. Pneumatics is considered an alternative energy source.

Potential Energy is the stored energy of an object due to its position.

Kinetic Energy is the energy a particle or object has because of its motion. When work is done on an object by applying a net force, the object speeds up and gains kinetic energy.

Actuator is in simple terms, it is a "mover". An **actuator** requires a control signal and a source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure, or even human power. ... An **actuator** is the mechanism by which a control system acts upon an environment.

Robot is a device that includes an input, a central processing unit (computer) to process the input and an output.

Work is the result of a force acting upon an object and resulting in displacement. When and object is displaced, it has moved some distances from its original position in the direction of the force that is being applied. The **work** done on an object by a net force equals the change in **kinetic energy** of the object: ... This relationship is called the **work-energy** theorem.

Power is the rate at which work is done or the rate at which energy is transfered from one place to another or transformed from one type to another.

Momentum is the property that a moving object has due to its mass and its motion.

Bernoulli's Principle says that a rise in pressure in a flowing fluid must always be accompanied by a decrease in the speed, and conversely a decrease in pressure of a fluid always results in an increase in speed.

Students are required to take Cornell Notes on the powerpoint and videos and the readings as well as the vocabulary including here as well as any other important vocabulary not listed. The following link will explain how to do the Cornell Notes, however many students are being trained on this. If the student does further research for his project, he should also take Cornell Notes on each reference he uses. All of the notes will be kept in the student's science notebook. The student should recieve a grade on the work in his science notebook.

https://www.wikihow.com/Take-Cornell-Notes