MechAnimations

(Grades 2-3)

City College of New York
www.citytechnology.org

MechAnimations (Grades 2-3)

Teacher's Guide

Overview

MechAnimations are home-made kinetic toys, which depict animals, people or scenes with movable parts. Students begin by making things from pegboard strips and boards. They learn to distinguish between structures and mechanisms, and learn how to make increasingly more complex linkages. These become the basis for understanding and making MechAnimations. They develop a visual language for representing and communicating their designs, learn to control the direction of motion, and investigate how the design of a linkage affects the distance traveled. In addition, they explore mechanisms made by others, such as nail clippers, salad tongs, nutcrackers and pliers. Finally, they create their final MechAnimations based on the knowledge they have developed about the design of mechanisms.

Common Core Learning Standards for ELA

<u>Common Core Writing Standards 2-3</u>

Text Types and purposes

2. Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately using linking words to sequence ideas and illustrations to aid comprehension.

3. Write narratives to develop real or imagined experiences using effective technique, descriptive details, and clear event sequences.

Production and Distribution of writing

4. Produce writing in which the development and organization are appropriate to task and purpose.

5. With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising and editing.

Research to Build and Present Knowledge

7. Conduct short research projects that build knowledge about a topic.

<u>Common Core Speaking and Listening Standards 2-3</u>

Comprehension and Collaboration

1. Engage effectively in a range of collaborative discussions with diverse partners, building on others' ideas and expressing their own clearly.

Presentation of Knowledge and Ideas

4. Recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace.

5. Add drawings or other visual displays to clarify ideas, thoughts and feelings.

<u>Common Core Language Standards 2-3</u>

Vocabulary acquisition and use

4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases, choosing flexibly from a range of strategies.

6. Acquire and use accurately general academic and domain-specific words and phrases.

Common Core Learning Standards for Mathematics

Standards for Mathematical Practice

MP1. Make sense of problems and persevere in solving them: Understand the meaning of a problem and look for entry points to its solution. Analyze givens, constraints, relationships and goals. Make conjectures about the form and meaning of the solution and plan a solution pathway.

MP2. Reason abstractly and quantitatively: Make sense of quantities and their relationships in problem situations. Abstract a given situation and represent it symbolically, Create a coherent representation of the problem at hand, attending to the meaning of quantities.

MP3. Construct viable arguments and critique the reasoning of others: Understand and use stated assumptions, definitions, and previously established results in constructing arguments. Reason inductively about data, making plausible arguments that take into account the context from which the data arose.

MP4. Model with mathematics: Identify important quantities in a practical situation, and map and analyze their relationships mathematically. Interpret mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

MP 7. Look for and make use of structure: Look closely to discern a pattern or structure.

Standards for Mathematical Content (Grades 2 & 3)

2. MD & 3.MD Measurement and Data
2.MD1-4: Measure and estimate lengths in standard units
2.MD 9 & 10; 3MD3 & 4: Represent and interpret data

2.G & 3.G Geometry
2.G1; 3G1: Reason with shapes and their attributes

Next Generation Science Standards/ Frameworks for K-12 Science Education

Dimension 1: Scientific and Engineering Practices:

1. **Asking questions and defining problems:** Students should be able to ask questions of each other about the phenomena they observe and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution.
2. **Developing and using models:** Students should be asked to use diagrams, maps and other abstract models to as tools that enable them to elaborate on their own ideas, develop explanations and present them to others.
3. **Planning and carrying out investigations:** In the elementary years, students' experiences should be structured to help them learn to define the features to be investigated, such as patterns that suggest causal relationships.
4. **Analyzing and interpreting data:** At the elementary level, students need support to recognize the need to record observations – whether in drawings, words or numbers – and to share them with others.

6. **Constructing explanations and designing solutions:** The process of developing a design is iterative and systematic, as is the process of developing an explanation in science. Elements that are distinctive in engineering include specifying constraints and criteria for desired qualities of the solution, developing a design plan, producing or testing models or prototypes, selecting among alternative design features, and refining design ideas based on the performance of a prototype.
7. **Engaging in argument from evidence:** In engineering, reasoning and argument are essential to finding the best possible solution to a problem. At an early design stage, competing ideas must be compared (and

possibly combined), and the choices are made through argumentation about the merits of the various ideas pertinent to the design goals.

8. **Obtaining, evaluating and communicating information:** In engineering, students need opportunities to communicate ideas using appropriate combinations of sketches, models and language. They should also create drawings to test concepts and communicate detailed plans; explain and critique models, and present both planning stages and ultimate solutions.

Dimension 2: Crosscutting concepts:

1. **Patterns:** Noticing patterns is often a first step to organizing and asking scientific questions about why and how the patterns occur. In engineering, it is important to observe and analyze patterns of failure in order to improve a design.

2. **Cause and effect: mechanism and prediction:** Any application of science, or any engineered solution to a problem, is dependent on understanding the cause-and-effect relationships between events. The process of design is a good place to start, because students must understand the underlying causal relationships in order to devise and explain a design to achieve a specified objective.

4. **Systems and system models:** A system is an organized group of related objects or components that form a whole. Models can be valuable in predicting a system's behaviors or in diagnosing its problems and failures. Students express their thinking with drawings or diagrams and with written or oral descriptions. They should describe objects in terms of their parts and the role those parts play in the functioning of the object.

6. **Structure and function:** The functioning of systems depends on the shapes and relationships of certain key parts, as well as on the properties of the materials. Exploration of the relationship between structure and function can begin in the early grades through investigations of accessible systems in the natural and human-built world.

Dimension 3: Disciplinary Core Ideas – Physical Science:

Core Idea PS1.A: Structure and Properties of Matter: Matter can be described and classified by its observable properties and by its uses. Different properties are suited to different purposes.

Core Idea PS2.A: Forces and Motion Interactions between any two objects can cause changes in one or both of them. Pushing and pulling on an object can change the speed and direction of motion.

Dimension 3: Disciplinary Core Ideas – Engineering, Technology and Applications of Science

Core Idea ETS1: Engineering Design

Identification of a problem and the specification of clear design goals, contending with constraints, using models to better understand the features of a design problem, compare designs, test them and compare their strengths and weaknesses. Selection of a design often requires making trade-offs among competing criteria.

Curriculum Map

Les-son	Title	Summary	Approx time (min.)	Vocabulary	Assessment Methods
1	**Making mechanisms and structures**	Introduction to pegboard materials and rivets; learning to make and identify mechanisms and structures	50	Mechanism, structure, pegboard, base, link, rivet	Observation, Discussion, writing
2	**The parts of a mechanism**	Creating mechanisms that produce specific motions, and exploring how the parts works together	100	Input, Output, Pivot, Control, Fixed pivot, Floating pivot, Lever, Input link, Guide, Direction of motion, Same, Opposite, cause , effect	Observation, discussion, writing, work products
3	**Representing a Mechanism**	Development of methods for diagramming their mechanisms, using a common visual language.	50	Drawing, diagram, symbol	Observation, discussion, drawing
4	**Designing a simple mechanism that animates a story**	Writing a story that could be told through the motion of a mechanism; design of the mechanism that will generate the motion and the images that will tell the story.	50	Design, plan	Observation, discussion, writing, drawing
5	**Exploring materials and using models**	Comparing materials for making mechanisms: pegboard vs. cardboard, rivets vs. paper fasteners exploring how use of a model can help to simplify the design of a mechanism	100	Material, compare, pegboard, cardboard, bend, flexible, cost, tradeoff, paper fastener, system, model	Observation, discussion, work products
6	**Making a simple MechAnimation**	Creating one-input/one-output MechAnimations that tells a story, based on the plans and the models from lessons 4 & 5.	100	Troubleshooting, issue, cause, fix	Observation, writing, work products
7	**Exploring manufactured mechanisms**	Examination of manufactured mechanisms to find the inputs, outputs, levers, pivots and directions of motion	50	Effort, fulcrum, load, force, simple lever, compound lever, mechanical advantage	Observation, discussion, writing, drawing
8	**Mechanisms with two outputs**	Exploring how two mechanism can be combined to create two output motions from one input.	100	Complex system, simple system, subsystem	Observation, discussion, writing, work products
9	**Controlling speed and distance**	Redesigning a mechanism to change how far and how fast one of the outputs travels, as both outputs are controlled by the same input.	100	Speed, distance, variable	Observation, discussion, writing, work products
10	**Designing a complex MechAnimation**	Planning and designing a MechAnimation with at least two outputs.	50		Observation, discussion, writing, drawing
11	**Making a complex MechAnimation**	Creating a MechAnimation with at least two outputs, based on the plans from Lesson 10	100		Observation, writing, work products
12	**The Mech-Animation Show**	Presenting Mechanimations to an audience, explaining how they were made and how they work	100		Writing, oral presentation

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Lesson	Title	Standards alignment				
		CCLS -- ELA	**CCLS -- Math**	**NGSS – Scientific & Engineering Practices**	**NGSS – Crosscutting Concepts**	**NGSS – Disciplinary Core Ideas**
1	**Making mechanisms and structures**	**Writing**: Text types and purposes; Production and distribution of writing **Language**: Vocabulary acquisition and use	MP2: Reason abstractly MP7: Look for and make use of structure	1. Asking questions and defining problems 8. Obtaining and evaluating information	1. Patterns 6. Structure and function	PS2.A: Forces and Motion
2	**The parts of a mechanism**	**Writing**: Text types and purposes **Speaking & Listening**: Comprehension and collaboration **Language**: Vocabulary acquisition and use	MP1: Make sense of problems	1. Asking questions and defining problems 6. Designing Solutions 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 6. Structure and function	PS2.A: Forces and Motion ETS1: Engineering Design
3	**Making a diagram that represents a mechanism**	**Writing**: Text types and purposes; Presentation of knowledge and ideas **Speaking & Listening**: Comprehension and collaboration **Language**: Vocabulary acquisition and use	MP2: Reason abstractly MP3: Construct viable arguments	2. Developing and using models 4. Analyzing and interpreting data 7. Engaging in argument from evidence 8. Obtaining, evaluating and communicating information	1. Patterns 4. Systems and system models 6. Structure and function	
4	**Designing a simple mechanism that animates a story**	**Writing**: Text types and purposes; Presentation of knowledge and ideas **Speaking & Listening**: Comprehension and collaboration **Language**: Vocabulary acquisition and use	MP6: Attend to precision MP7: Look for and make use of structure 2.G1 & 3G: Reason with shapes & their attributes	1. Asking questions and defining problems 6. Designing solutions 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 6. Structure and function	PS2.A: Forces and Motion ETS1: Engineering Design

Lesson	Title	Standards alignment				
		CCLS -- ELA	CCLS -- Math	NGSS – Scientific & Engineering Practices	NGSS – Crosscutting Concepts	NGSS – Disciplinary Core Ideas
5	**Exploring materials and using models**	**Writing**: Production and distribution of writing **Language**: Vocabulary acquisition and use	MP4: Model with mathematics	2. Developing and using models 7. Engaging in argument from evidence 8. Obtaining, evaluating and communicating information	1. Patterns 4. Systems and system models 6. Structure and function	PS1.A: Properties of Matter
6	**Making a simple MechAnimation**	**Writing**: Production and distribution of writing **Language**: Vocabulary acquisition and use **Speaking & Listening**: Comprehension and collaboration; presentation of knowledge and ideas		3. Planning and carrying out investigations	1. Patterns 6. Structure and function	PS2.A: Forces and Motion ETS1: Engineering Design
7	**Exploring manufactured mechanisms**	**Writing**: Text types and purposes; Research to build and present knowledge **Speaking & Listening**: Comprehension and collaboration; presentation of knowledge and ideas **Language**: Vocabulary acquisition and use	MP2: Reason abstractly MP6: Attend to precision MP7: Look for and make use of structure 2.G1 & 3G: Reason with shapes & their attributes 2.MD 1-4: Measure and estimate lengths 2. MD 9&10; 3.MD 3&4: Represent and interpret data	3. Planning and carrying out investigations 4. Analyzing and interpreting data 7. Engaging in argument from evidence 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 6. Structure and function	PS1.A: Properties of Matter PS2.A: Forces and Motion
8	**Mechanisms with two outputs**	**Writing**: Text types and purposes; Research to build and present knowledge **Speaking & Listening**: Comprehension and collaboration **Language**: Vocabulary acquisition and use	MP2: Reason abstractly MP4: Model with mathematics MP7: Look for and make use of structure	1. Asking questions and defining problems; 2. Developing and using models; 3. Planning and carrying out investigations: 4. Analyzing and interpreting data; 6. Designing Solutions; 7. Engaging in argument from evidence; 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 4. Systems and system models 6. Structure and function	PS2.A: Forces and Motion ETS1: Engineering Design

Lesson	Title	Standards alignment				
		CCLS -- ELA	**CCLS -- Math**	**NGSS – Scientific & Engineering Practices**	**NGSS – Crosscutting Concepts**	**NGSS – Disciplinary Core Ideas**
9	**Controlling speed and distance**	**Writing**: Text types and purposes; Research to build and present knowledge **Speaking & Listening**: Comprehension and collaboration **Language**: Vocabulary acquisition and use	MP2: Reason abstractly MP4: Model with mathematics MP7: Look for and make use of structure 2.MD 1-4: Measure and estimate lengths 2. MD 9&10; 3.MD 3&4: Represent and interpret data	1. Asking questions and defining problems; 2. Developing and using models; 3. Planning and carrying out investigations: 4. Analyzing and interpreting data; 6. Designing Solutions; 7. Engaging in argument from evidence; 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 4. Systems and system models 6. Structure and function	PS2.A: Forces and Motion ETS1: Engineering Design
10	**Designing a complex MechAnimation**	**Writing**: Text types and purposes; Research to build and present knowledge **Speaking & Listening**: Comprehension and collaboration		1. Asking questions and defining problems 6. Designing Solutions 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 6. Structure and function	ETS1: Engineering Design
11	**Making a complex Mech-Animation**	**Writing**: Text types and purposes; Production and distribution of writing; Research to build and present knowledge		1. Asking questions and defining problems 6. Designing Solutions 8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 6. Structure and function	ETS1: Engineering Design
12	**The Mech-Animation Show**	**Writing**: Text types and purposes; **Speaking & Listening**: Comprehension and collaboration; presentation of knowledge and ideas		8. Obtaining, evaluating and communicating information	1. Patterns 2. Cause and effect: mechanism and prediction 6. Structure and function	ETS1: Engineering Design

Teaching Strategies

Learning: People learn by doing, and then reflecting on what they have done. In engineering, the goal is to design and create something new, and new designs rarely work well the first time. The effort to troubleshoot and fix something that doesn't work provides rich motivation for learning. This curriculum unit provides numerous opportunities for students to explore for themselves, make things based on what they have learned, and reflect on their work in both oral and written form. Just as there is no one way to design something new, there is no one way to teach this unit. Be creative and flexible, and your students will be too!

Vocabulary: Words are not very meaningful unless they are connected with concepts. For this reason, we do not believe in presenting vocabulary words at the beginning of a lesson. Provide students with experiences that allow them to develop the concepts for themselves, and encourage them to use *their own words* to describe these concepts. *Then* provide the words that professional scientists and engineers use to describe these same concepts. These are the words provided in the Vocabulary column of the curriculum maps and the Word Bank section of each lesson. The Glossary at the end of this unit provides a working definition for each word.

Writing and Drawing:

Writing and drawing are essential parts of engineering design. The person who created something new is the only person who can describe what they did, and is may be strongly motivated to convey these original ideas to others. This curriculum unit provides numerous opportunities for students to make sense of what they have done through text and graphics. They are encouraged to describe what they plan to make, the issues that prevented it from working, how someone else could make it, how it works and what was learned from it.

As much as possible, students need to express themselves in their own words (see Vocabulary, above), with no more prompts than necessary to get them started. The boxes labeled Science Notebook and the worksheets in the lessons provide starting points. These can be used in any combination, and students should also have opportunities to do more open-ended writing, for example to reflect on how they feel about their work.

Science Notebook entries are boxed.
🗲 Writing prompts have lightning bullets.

Writing in notebooks and worksheets is primarily for the students themselves – to help them consolidate and remember what they have learned and communicate it to others – but it also serves as an assessment tool. It should not be marked closely for grammar and spelling. However, it is appropriate to ask students to read what they have written to the class, and to challenge them to clarify ideas that are unclear or incomplete. Much of the description will require drawings or diagrams as well as text, and it is important to help students learn to coordinate these two modes of communication.

Discussion:

Speaking and listening are essential forms of literacy and are central to learning science and engineering. The purpose of a discussion, like that of writing and drawing, is to create meaning. A discussion is not a question-and-answer session led by the teacher, nor a sharing session in which students simply report on what they did. Making meaning requires that students listen and respond to one another's ideas. In a discussion of engineering design, students may want to bring up issues that they have encountered. Other students may respond by identifying similar issues, and/or by suggesting solutions that they have come up with. As the teacher, your role is to facilitate this give-and-take, by posing questions for discussion and then maintaining focus within the group. Sample focusing questions are identified like this within each lesson:

- 🗲 *Lightning bullets and italics indicate prompts for discussion*

Reference: Worth, K., Winokur, J. Crissman, S., Heller-Winokur, M. (2009) The Essentials of Science and Literacy: A Guide for Teachers. Portsmouth, NH: Heinemann.

Structure of the Lesson Plans

The following categories appear in each lesson (*), or most lessons (**):

***Essential Question**

***Task**

***Standards**

***Outcomes**

***Assessment**

****Advance Preparation**

***Materials**

***Procedure**

****Word bank**

****Worksheets**

Overview of Basic concepts

Any device with independently moving parts is a **mechanism**. An object that can move only as a whole, and therefore has no moving parts, is called a **structure**. Examples of mechanisms are scissors, clothespins, nail clippers, tubes of lipstick or glue stick, salad tongs and folding chairs. To operate a mechanism, you apply a **force** to the **input**, causing it to move. The force and motion at the input result in both force and motion at the **output**, the part that does the job the mechanism is designed to do. For example, to operate a pair of nail clippers, you apply a force on the handles, which are the inputs of the device. As you squeezing the handles together, the mechanism of the nail clipper transfers the force and motion to the two cutting jaws, which are the outputs. When these come together, they apply a force to a fingernail or toenail, cutting off a piece. The jaws are the outputs, because they do the job the nail clipper is intended for.

Most mechanisms are designed to make work easier, by reducing the amount of force needed at the input, compared with the force delivered at the output. Science books often refer to the "six simple machines": the lever, wheel-and-axle, pulley, inclined plane, wedge and screw. This is far too complicated! There are only two mechanical devices for achieving the reduction in force described above: the **lever** and the **inclined plane**. The other four "simple machines" are based on these two: the wheel-and-axle and pulley both rely on levers, while the screw and wedge incorporate inclined planes. This curriculum focuses on **linkages**, which are systems of levers.

Any lever or a linkage is made of several basic components. There is usually a **base** that remains stationary while the other parts are moving, and serves to hold things together. The bottom jaw of a nail clipper is a base, but a pair of scissors has no base, unless you hold one of the arms fixed while you move the other. The moving parts are rigid bars called **links**. These are connected to each other and to the base by **pivots** that allow the links to rotate. Links come in two types: those that are tied to the base by a pivot are called levers, while those that are used to move the input of a lever are called **input links**. A basic mechanism consists of a base, an input link and a lever. The input link is used to make the lever move from a distance – i.e., to **control** it. A device for keeping the motion of a link along a straight line is called a **guide**.

In the language of simple machines, the input to a lever is called the **effort**, and the output is called the **load**. The function of a lever can be to change the **direction** of motion, the **speed** and/or the amount of **force** between the effort and the load. A lever is able to do this because it is attached to the base by a pivot, which is called a **fulcrum.** The pivot that attaches a lever to the base allows the lever to rotate, but does not itself move – it is a **fixed pivot**. If the effort is further from the fulcrum than the load, the amount of force will be less at the input than at the ouput. The ratio of these two, output force to input force, is called the **mechanical advantage**.

A mechanism is an example of a **system**, because it has inputs and outputs. Most systems have multiple inputs and/or multiple outputs. If a single input controls more than one output, the input plus each output constitutes a **subsystem**, which is part of a larger system, but which could function as a system by itself. Because a system can be complex, it is very useful to describe one by creating a **model**, which shows the major features of the real thing, but leaves out aspects that get in the way of understanding. A **physical model** of a mechanism works like the real mechanism, but is easier to put together and does not include the images or the story. In MechAnimations, students use **pegboard** bases and strips, plus aluminum **rivets** to make physical models, in order to try out their ideas for making mechanisms. They later transfer these ideas to their final products, which are made of **cardboard** and **paper fasteners**. Each set of materials has its own **pros and cons**: pegboard and rivets are easier to use, but more expensive, and harder to customize; while cardboard and paper fasteners are harder to use, but cheaper and easier to customize.

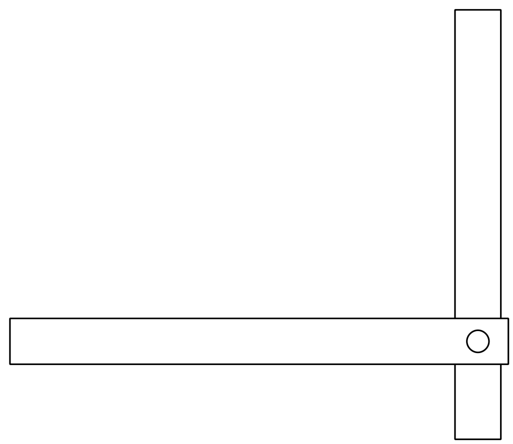
Another kind of model is a two-dimensional **diagram**, which is different from a drawing, because it uses **standard symbols** to **represent** real things. Scientists and engineers use diagrams to exchange ideas and develop new ones. Agreeing on standard symbols makes it easy for different people to interpret each other's diagrams.

Teacher Notes on the Lessons

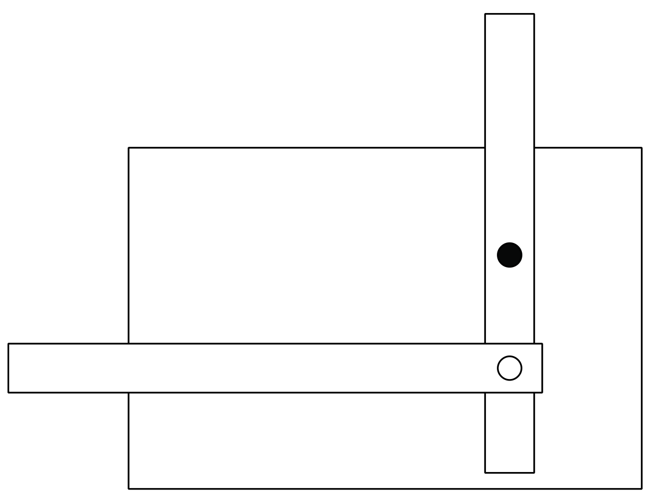
Lesson 1: Mechanisms and Structures

How to make the Butterfly-and-Net MechAnimation:

1. You will need:
    - 1 cardboard base, 8 1/2 " x 11"
    - 2 cardboard strips, 1" x 11"
    - 2 paper fasteners
    - Sharp pencil
    - Templates for butterfly, net and "garden scene" cover
    - Clear tape
2. Lay the two strips at right angles, as shown below. Poke a hole in each one and join them with a paper fastener near their bottom right ends. The paper fastener's legs should be pointing towards you:



3. Attach the vertical strip to the base using the other paper fastener, about midway along the length of the strip. The fastener is the fixed pivot. This time the head should be up, and the legs should be on the other side of the base:

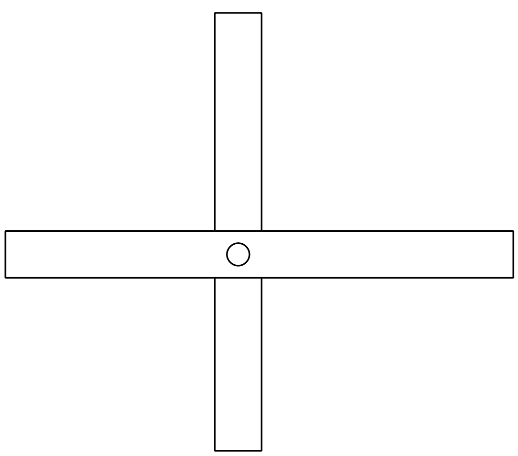


4. Test it. The output (vertical strip) should move to the left as the input (horizontal strip) moves to the right.

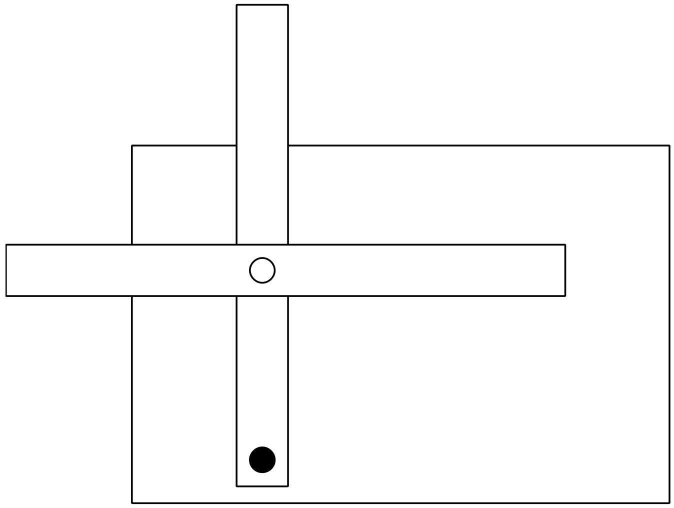
5. Tape the "Garden scene" cover over the base, making sure the strips are still free to move. Cut out the net and butterfly from the templates. Tape the net to the output and attach the butterfly to the cover. Test it again. Adjust the butterfly and net if necessary.
6. The finished product is shown below in both positions:

How to make the <u>Hammer-and-Nail</u> MechAnimation:

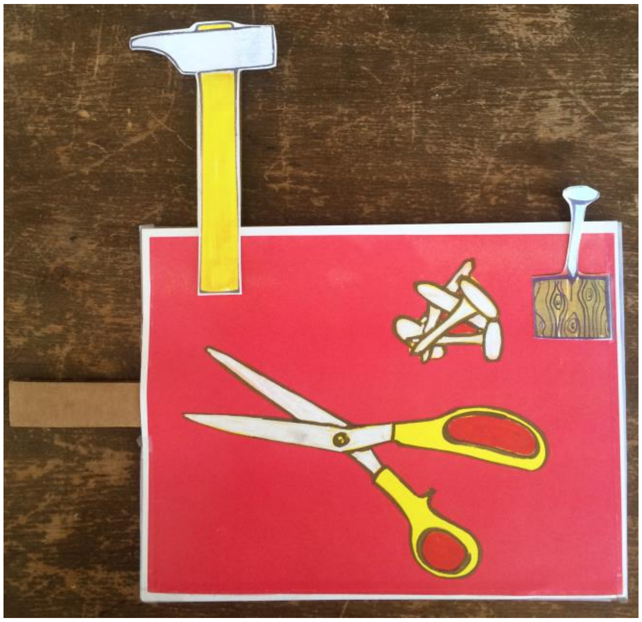
1. You will need:
   - 1 cardboard base, 8 1/2 " x 11"
   - 2 cardboard strips, 1" x 11"
   - 2 paper fasteners
   - Sharp pencil
   - Templates for hammer, nail and "Tool Assortment"cover
   - Clear tape and scissors
2. Lay the two strips at right angles, as shown below. Use the pencil to poke a hole in each one and join them with a paper fastener near the middle of each one. The paper fastener's legs should be pointing towards you:



3. Attach the vertical strip to the base using the other paper fastener, about midway along the length of the strip. The fastener is the fixed pivot. This time the head should be up, and the legs should be on the other side of the base:



4. Test it. The output (vertical strip) should move to the right as the input (horizontal strip) moves to the right.
5. Tape the “Tool Assortment” cover over the base, making sure the strips are still free to move. Cut out the hammer and nail from the templates. Tape the hammer to the output and attach the nail to the cover. Test it again. Adjust the hammer and nail if necessary.
6. The finished product is shown below in both positions:



Inserting and removing rivets

Students may have difficulty using the rivets. To get them into the holes in the pegboard, it sometimes helps to push them through with the back of a pencil or marker, or to turn the base or strip upside down, so the head is against the table, and push down. To get them out, turn the pegboard over and use the same method to push the narrower side back the other way.

Mechanisms and structures

Any device that has moving parts is a **mechanism**. If something has no moving parts, it is called a **structure**. A structure can move only as a unit – all the parts have to travel together. A desk, chair, box, board or stick is a structure, either because it has only one part, or because none of its parts is supposed to move independently of the other parts. A pair of scissors, stapler, tweezers, door lock or skateboard each has moving parts, so it is a mechanism. A wise person wrote, "*There are only two tools you'll ever need: Duct Tape and WD-40™. Here's how you'll know which one to use: if it moves and it shouldn't move, use duct tape; if the opposite is true, use WD-40™"*. In our terminology, Duct Tape converts a mechanism into a structure, while, WD-40™ changes a structure into a mechanism!

The Worksheet provides eight examples of constructions that could be structures or mechanisms, and asks students to determine which is which – see Figure 1 below. A good way to find out is to make each one in pegboard, and see if it has moving parts.

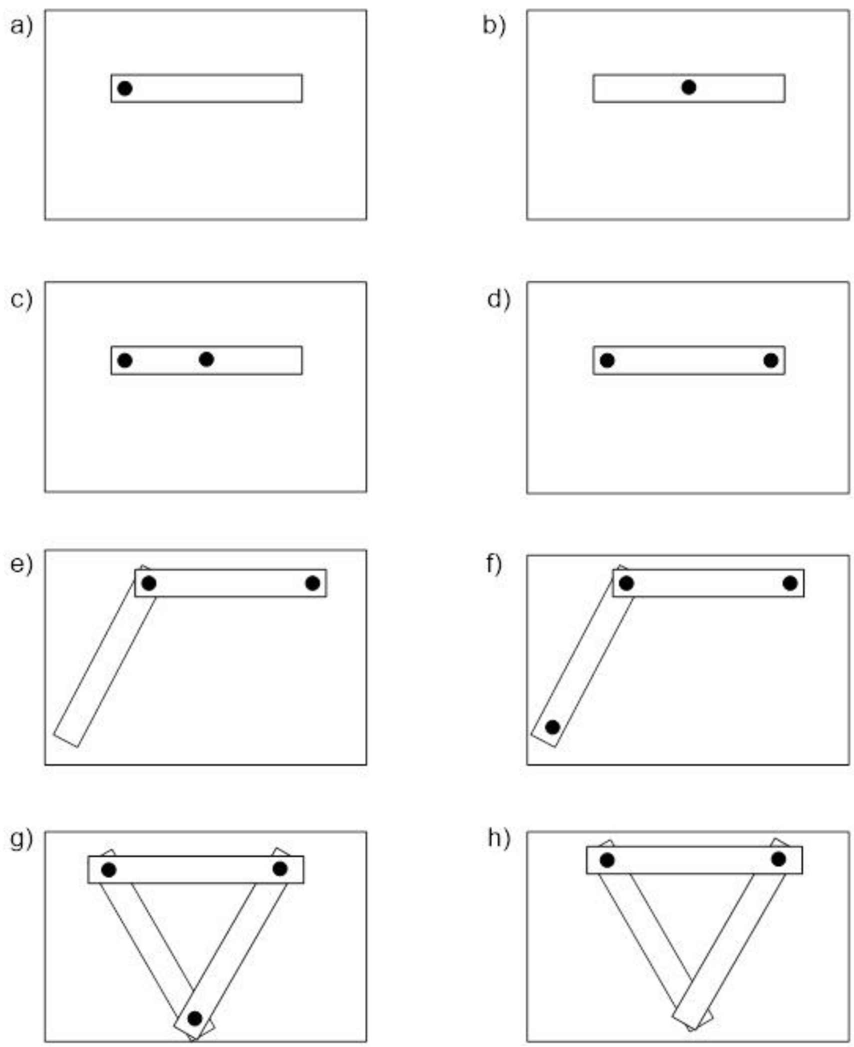


Figure 1: Structure or mechanism?

The strips in a) and b) are <u>mechanisms</u>. Each strip is free to rotate, because each is held by only one rivet. However, the strips in c), d) f), and g) cannot move unless the base does too, because the fasteners hold them securely in the same position on the base. These are <u>structures</u>. Examples e) and h) are also mechanisms, even thought one strip in each one is tied to the base. In e) a second strip is free to rotate, while in h) two out of three strips can rotate, making both e) and h) mechanisms. To change a structure into a mechanism, you have to remove rivets, while to go the other way, you have to add them.

Making one strip control another

An obvious way to attempt the design challenge would be simply to push the first strip with a second. In Figure 2, a) shows the original strip X. In b), another strip Y is lined up with the bottom of X, and in c), used to push the bottom of X to the right. However, this method does not satisfy the goal of controlling X, as you can see in 2 d). When Y is pulled back to the left, X does not go with it. In order for Y to control X, it needs to be attached to it somehow. Would it work to to put a fastener through X, Y and the base, as shown in Figure 2 e)? No, because now X can't move at all! Putting two rivets through both the strip and the base has made strip X plus the base into a structure, as in Figure 1c), d), f) and g).

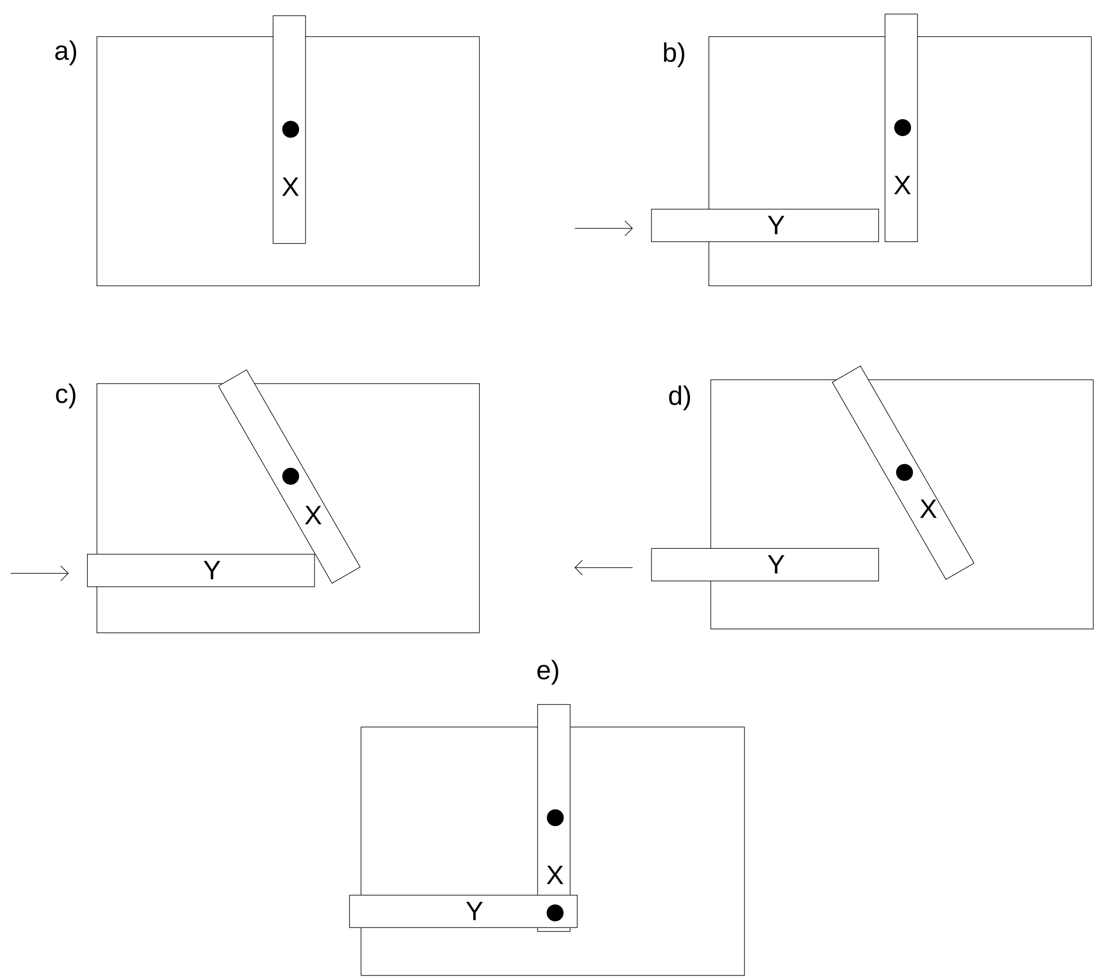


Figure 2: Several attempts to make strip Y control strip X

The solution is to use a rivet that connects X and Y to *each other*, but *not to the base.* The easiest way to accomplish this is to first put a rivet between strips X and Y, as in Figure 3 a). Then attach X to the base, as in Figure 3 b). Once a rivet goes through the base, it is not free to move, but it may allow a strip to move. We'll call a rivet that can't move itself, but allows a strip to rotate, a **fixed pivot**. A rivet that can move with a strip, because it is not attached to the base, is called a **floating pivot**. Any strip that can move is a **link**. In Figure 4, the floating pivot is shown by an open circle, while the fixed pivot is shown by a black circle.

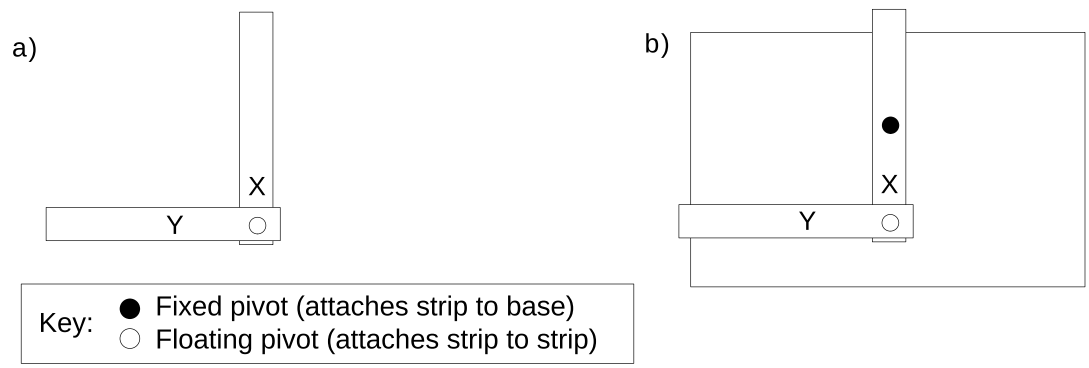


Figure 3: Assembling a mechanism in which one strip controls another

The result is a mechanism that meets the challenge, as shown in Figure 4. Pulling Y to the left rotates X clockwise (Figure 4 a)), while pushing it to the right rotates X counterclockwise. (Figure 4 b))

Figure 4: Strip Y now controls strip X

One remaining issue is how to restrict link Y so it moves only back-and-forth, so it cannot rotate up and down, as shown in Figure 5 a). Figure 5 b) shows a simple solution: insert a pair of rivets into the base, above and below link Y, that keep it moving horizontally. These two rivets serve as a **guide** for restricting the motion of Y to a horizontal line.

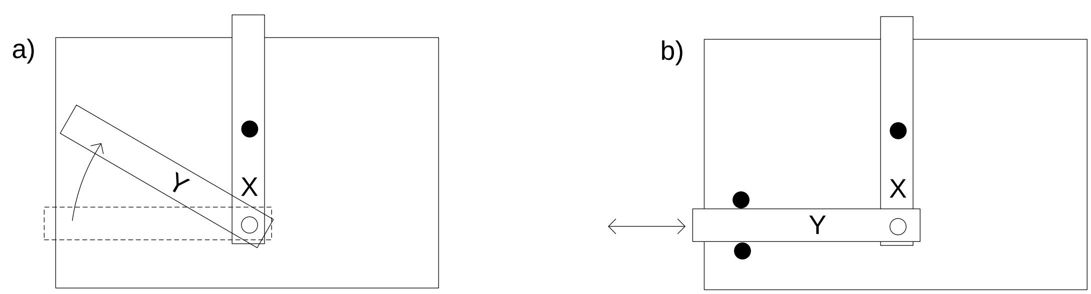
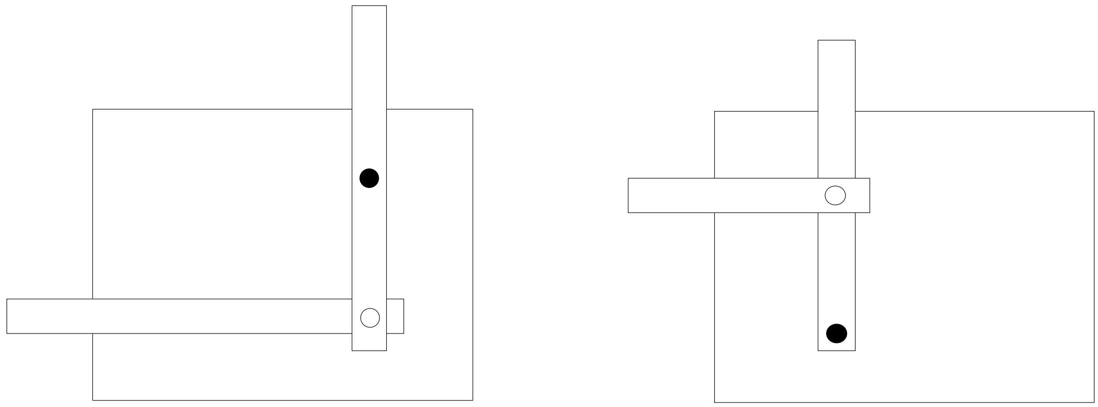


Figure 5: To keep link Y from rotating up and down, as in a), use a pair of rivets to make a **guide**, as in b)

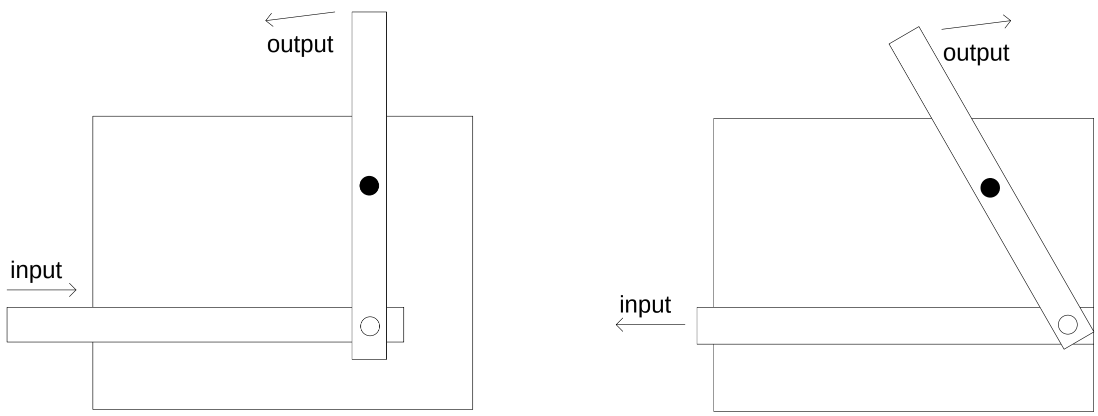
Direction of Motion

The input and output move in opposite directions in the Butterfly-and-Net and in the same direction in the Hammer-and-Nail.In the Butterfly, the fixed pivot is in between the input link and the output, which causes them to turn in opposite directions. In the Hammer, the fixed pivot is below both the input link and the output, so they move in the same direction. Figure 6 shows the two constructions, Figure 7 shows the motion of the Butterfly-and-Net as the input moves right and left, and Figure 8 is a similar diagram for the Hammer.



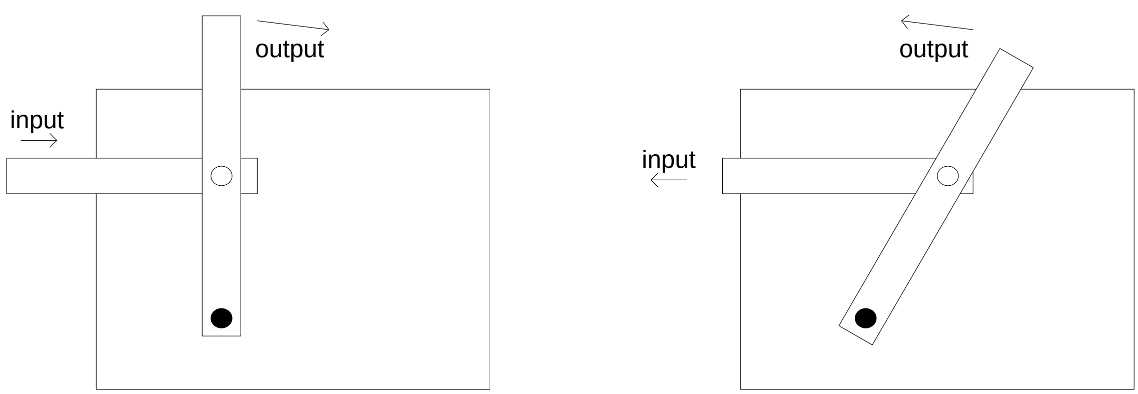
a) Butterfly b) Hammer

Figure 6: The mechanisms inside the Butterfly-and-Net and the Hammer-and-Nail



a) Input moves to the right b) Input moves to the left

Figure 7: Motion of the Butterfly-and-Net output as the input moves a) right and b) left



a) Input moves to the right b) Input moves to the left

Figure 8: Motion of the Hammer-and-Nail output as the input moves a) right and b) left

Figure 9 shows the Hammer-and-Nail mechanism made in pegboard. Note the fixed pivot below the floating pivot. In the Butterfly-and-Net, these would be reversed.

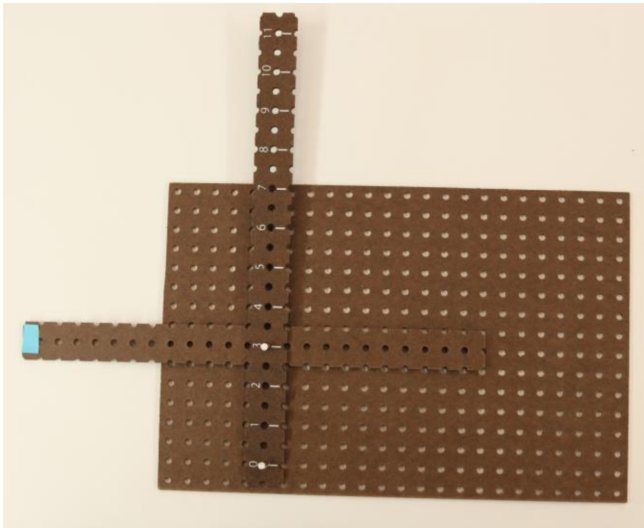


Figure 9: The Hammer-and-Nail mechanism, constructed in pegboard.

Naming the Parts

The names can be confusing. Figure 10 is a diagram showing the parts of a typical MechAnimation, in this case, the Butterfly-and-Net

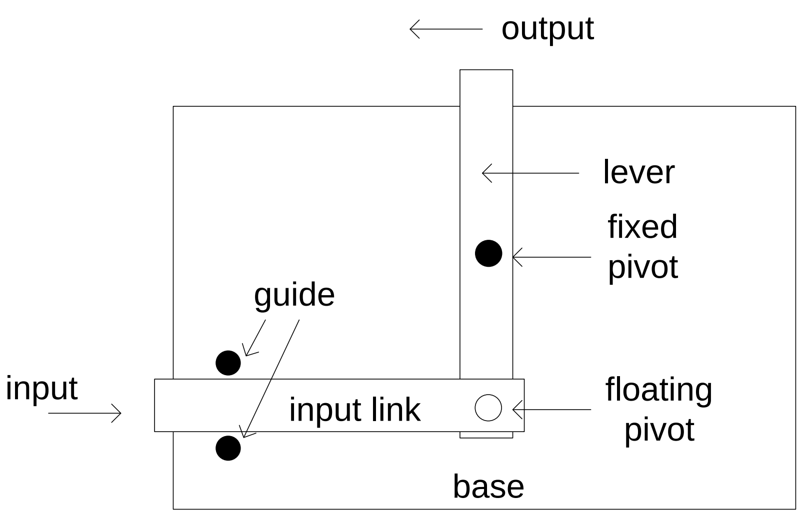


Figure 10: The parts of a mechanism

In Lesson 3, Representing a Mechanism, students will be creating their own diagrams of this kind.

Lesson 4: Designing a Simple Mechanism that Animates a Story

Coming up with an idea for a Mechanimation

When students begin designing their MechaAnimations, encourage them to be creative. They will likely come up with some very good ideas. If some students are having difficulty in thinking of ideas, here are some suggestions:

a) Show students an MechAnimation you or previous students have made;

b) Share the examples listed below;

c) Connect the MechAnimations to a current class theme.

In brainstorming, there are no bad ideas, and nobody is committed to pursuing any idea they come up with, so it should be a risk-free environment. The point of brainstorming is for students to get ideas from one another. Here are some ideas students have come up with in the past:

- A sneaker steps on a cockroach
- A meteor hits a building
- A tennis racquet or baseball bat hits a ball
- A hand throws a football
- A foot kicks a soccer ball
- Dunking a basketball
- A car moves down a road
- Feeding a bottle to a baby
- A fishing pole catches a fish
- Swatting a fly
- An airplane or helicopter takes off.

If students come up with ideas that seem very complex, such as ones requiring multiple outputs, suggest they record them and save them for later. In Lessons 8 & 9, we will be learning about mechanisms with multiple outputs, and the final project in Lessons 10 & 11 will focus on making more complex MechAnimations.

Lesson 5: Exploring Materials and Using Models

The following table presents some examples that could appear in the chart of models:

System	Model	How are they similar?	How are they different?
Car	Toy car	Both have wheels, can travel	Model is smaller, has no motor, nor passengers
Territory	Map	Same locations	Map is much smaller, is 2D, does not show everything
MechAnimation	Mechanism diagram	Same strips and pivots	Diagram is 2D, does not move
MechAnimation	Pegboard model	Same strips and pivot, both are 3D	Model does not tell story
Person	Doll	Both have faces, arms, legs and clothes	Doll is much smaller, not alive
Legos	Instructions	Show the same pieces, show how they fit together	Diagram is smaller, 2D

Lesson 6: Making MechAnimations

The table below shows typical issues that might arise, as well as a possible cause and fix for each one:

Issue	Cause	Fix
Nothing Moves	One of the strips is part of a structure	Replace fixed pivot with floating pivot
Mechanism begins to move but then hangs up	Paper fastener is getting stuck	Turn paper fastener around so legs are pointing up and head is sliding against base
Input link flops around too much	Nothing is preventing vertical motion	Add a guide to keep input moving horizontally
Motion is smooth, but does not resemble pegboard model	Pivots are not in the same places	Make new holes for pivots, in similar locations to those in pegboard model

Lesson 7: Exploring Manufactured Mechanisms

Figure 11 shows some common mechanisms, with the effort, fulcrum and load labeled on each one:

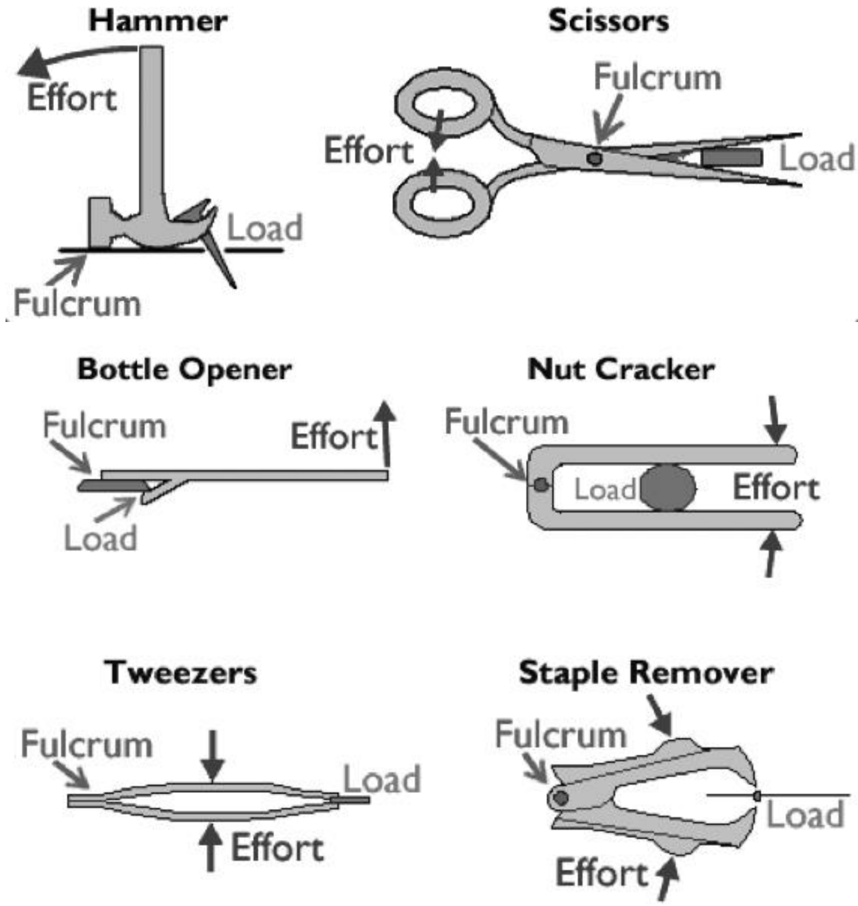


Figure 11: Common mechanisms, showing lever parts

A nail clipper includes two levers: the handle and the upper jaw. It is a compound lever, because the output (load) of the handle is the input (effort) of the upper jaw. Figure 12 shows the parts of each lever.

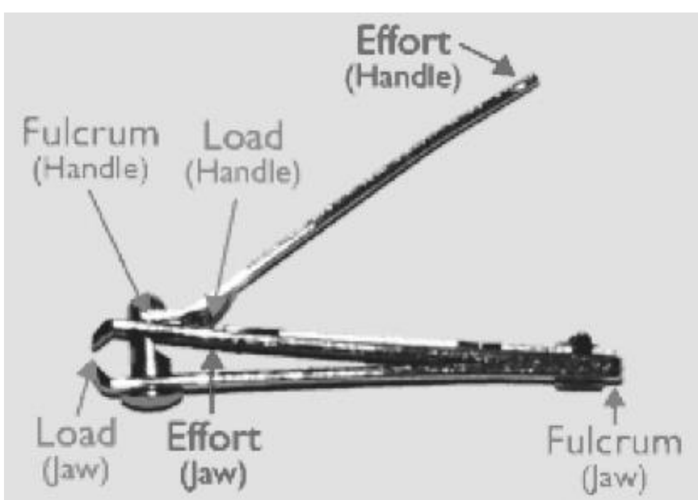
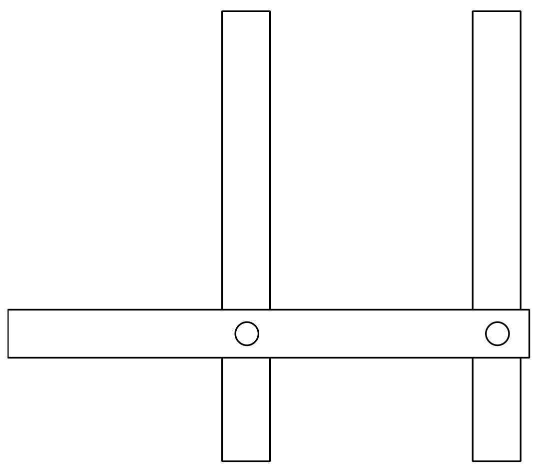


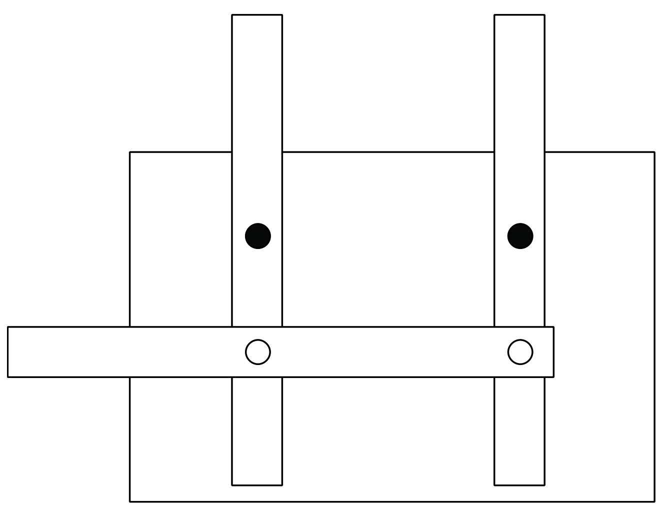
Figure 12: The nail clipper

How to Make the Sample Same-Direction Windshield Wiper MechAnimation:

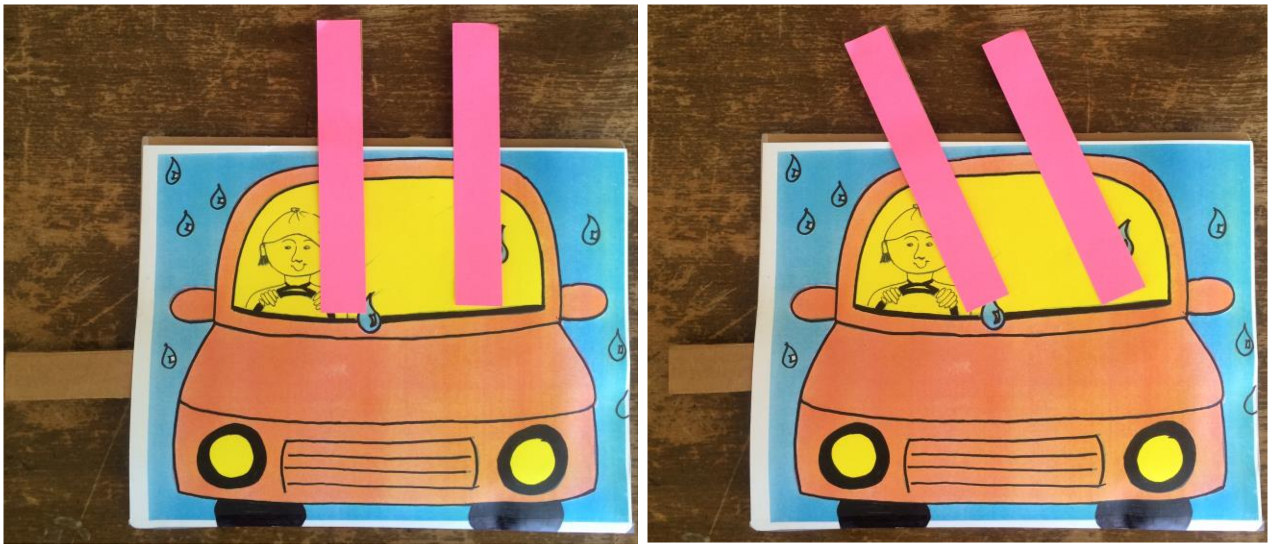
1. You will need:
   - 1 cardboard base, 8 1/2 " x 11"
   - 3 cardboard strips, 1" x 11"
   - 4 paper fasteners
   - Sharp pencil
   - Printed "Windshield" cover and blank sheet of colored cardstock for windshield wipers
   - Clear tape and scissors
2. Lay the three strips in the "H" pattern shown below. The two parallel strips should be vertical. They should cross the horizontal strip about one-quarter of the way up. The horizontal strip should extend past the vertical strips to the left. Poke holes in all three strips where they cross and insert two paper fasteners through holes. The paper fasteners' legs should be pointing towards you:



3. Attach the vertical strip to the base using the other two paper fasteners, at about midway up the height of the strips. These are the fixed pivots. This time the heads should be up, and the legs should be on the other side of the base:

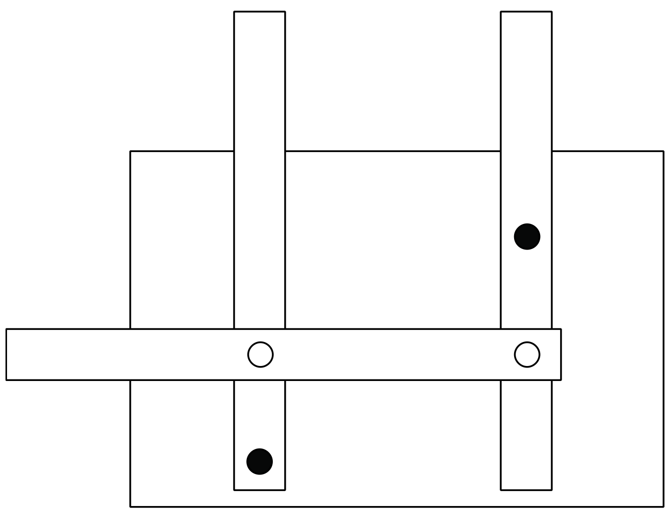


4. Test it. Both outputs (vertical strips) should move to the left as the input (horizontal strip) moves to the right.
5. Tape the “Windshield” cover over the base, making sure the strips are still free to move. Cut out strips from the blank sheet of cardstock to make the windshield wipers. Tape the windshield wipers to the tops of the two strips, and allow them to overlap the windshield..
6. The finished product is shown below in both positions:



How to Make the Sample <u>Opposite-Direction</u> Windshield Wiper MechAnimation:

The materials and method for making this MechAnimation is the same as for the Same-Direction Windshield Wipers, except the location of the fixed pivots in step 3, which are shown below:



The finished product is shown below in both positions:

Two-output mechanisms

In the Same-Direction mechanism, because both outputs move the same way, they must both be made the same way. Both are Butterfly-and-Net mechanisms because the two outputs move in the same direction as each other, but in the opposite direction from the input. Figure 13 shows how to combine two Hammer-and Nail mechanisms to make the Same-Direction Windshield Wipers:

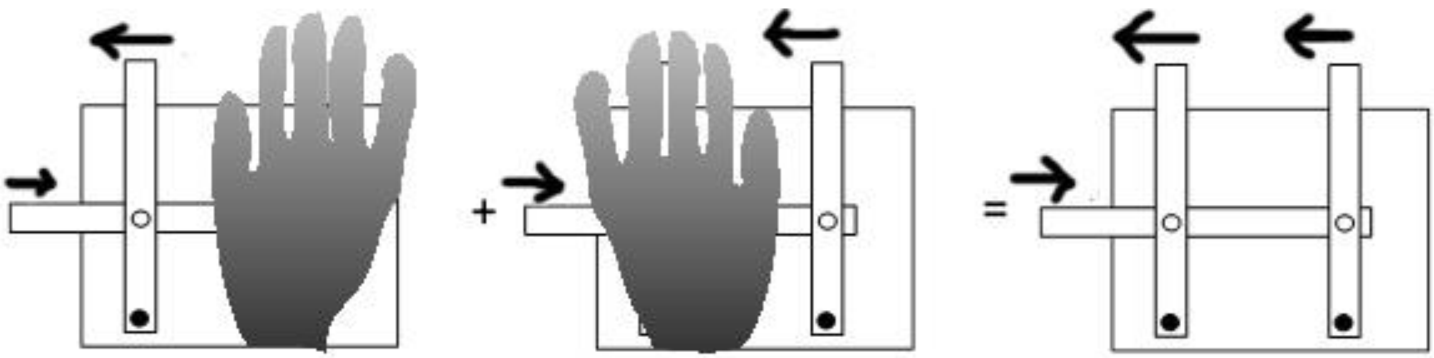


Figure 13: How two Butterfly-and-Net Mechanisms combine to make Same-Direction Windshield Wipers

In the Opposite-Direction mechanism, the two outputs must be constructed differently in order to move in opposite directions. The left side is like the Hammer-and Nail because it moves in the same direction as the input. However the right side moves the other way – opposite to the input – so it must be like the Butterfly-and-Net. Figure 14 shows how to combine these two to make the Opposite-Direction Windshield Wipers.

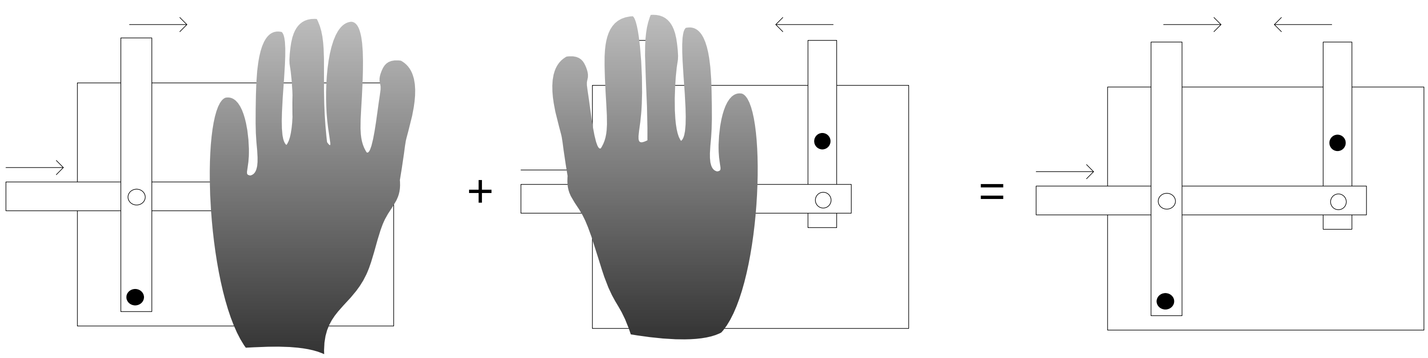


Figure 14: How to make an Opposite-Direction Windshield Wipers from a Hammer-and-Nail (left) and a Butterfly-and-Net (right)

The completed pegboard model of the Opposite-Direction Windshield Wipers is shown below, in Figure 15:

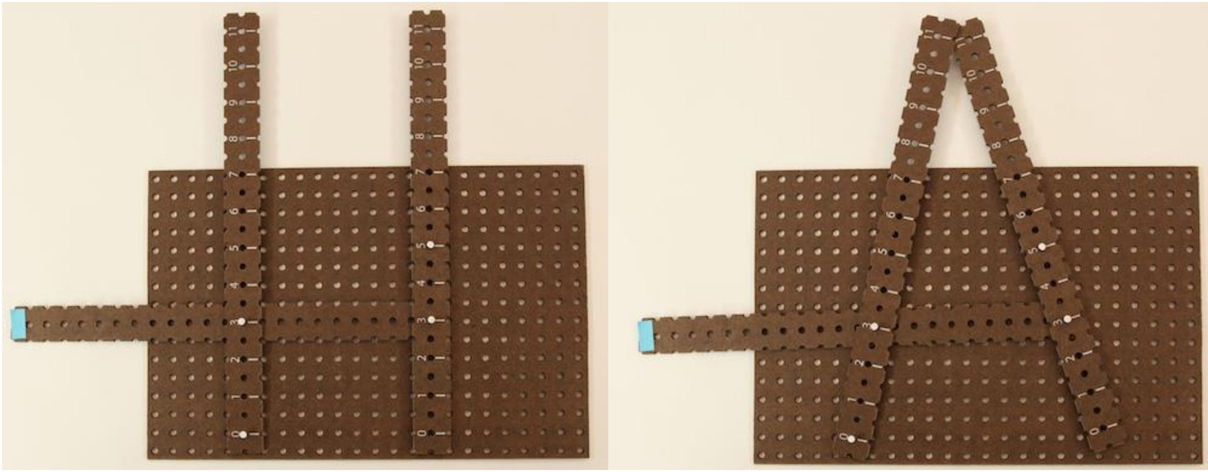


Figure 15: Opposite Direction Windshield Wipers, in both positions

Mystery Mechanisms

Some students may find the Windshield Wipers mechanisms too easy to design and make, or may have extra time, and therefore need additional challenges. Figure 16 shows the input and output motions of some "Mystery Mechanisms they could try to create:

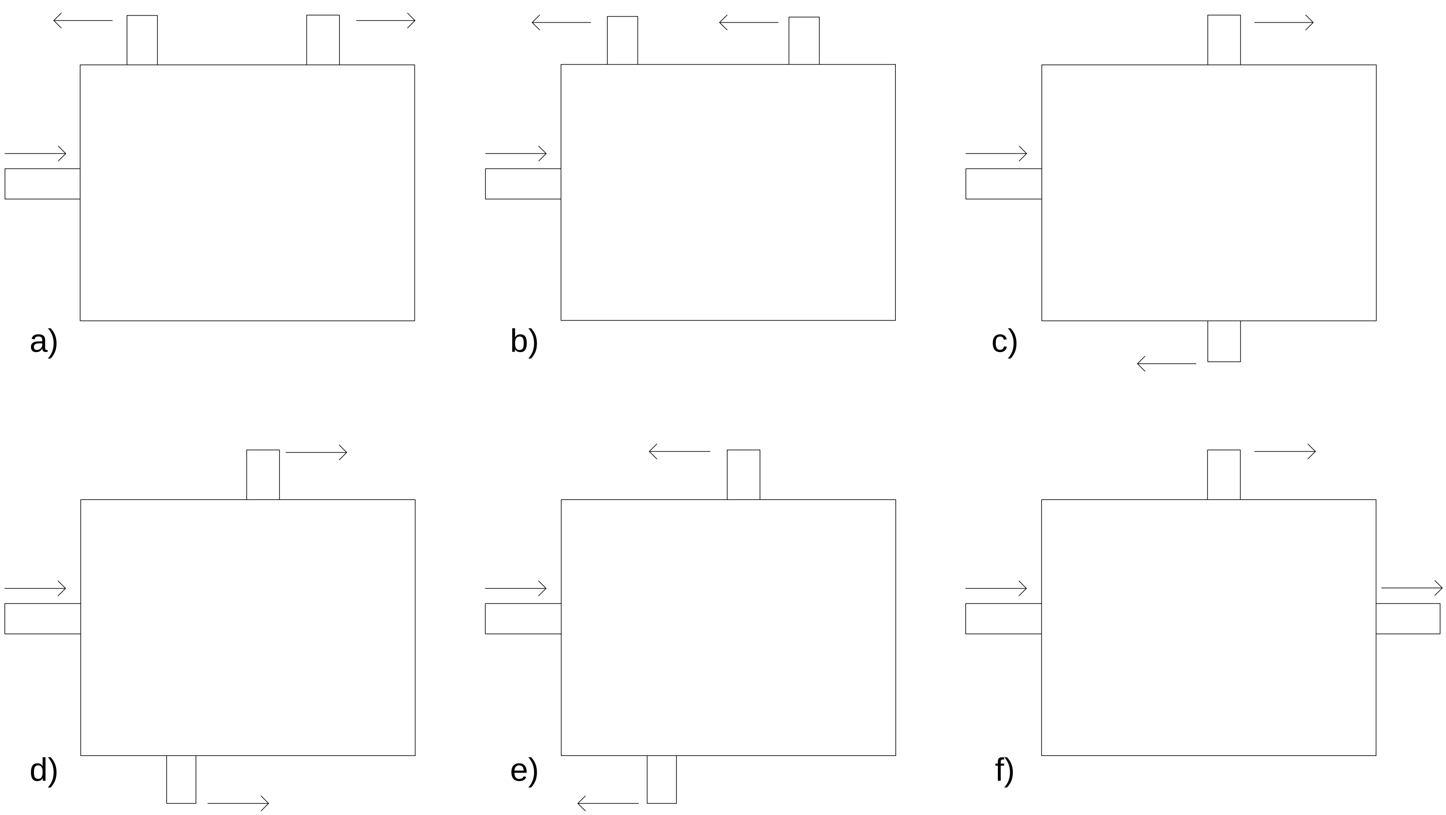


Figure 16: Mystery Mechanisms challenges: How could you make each one?

The solutions are given below in Figure 17.

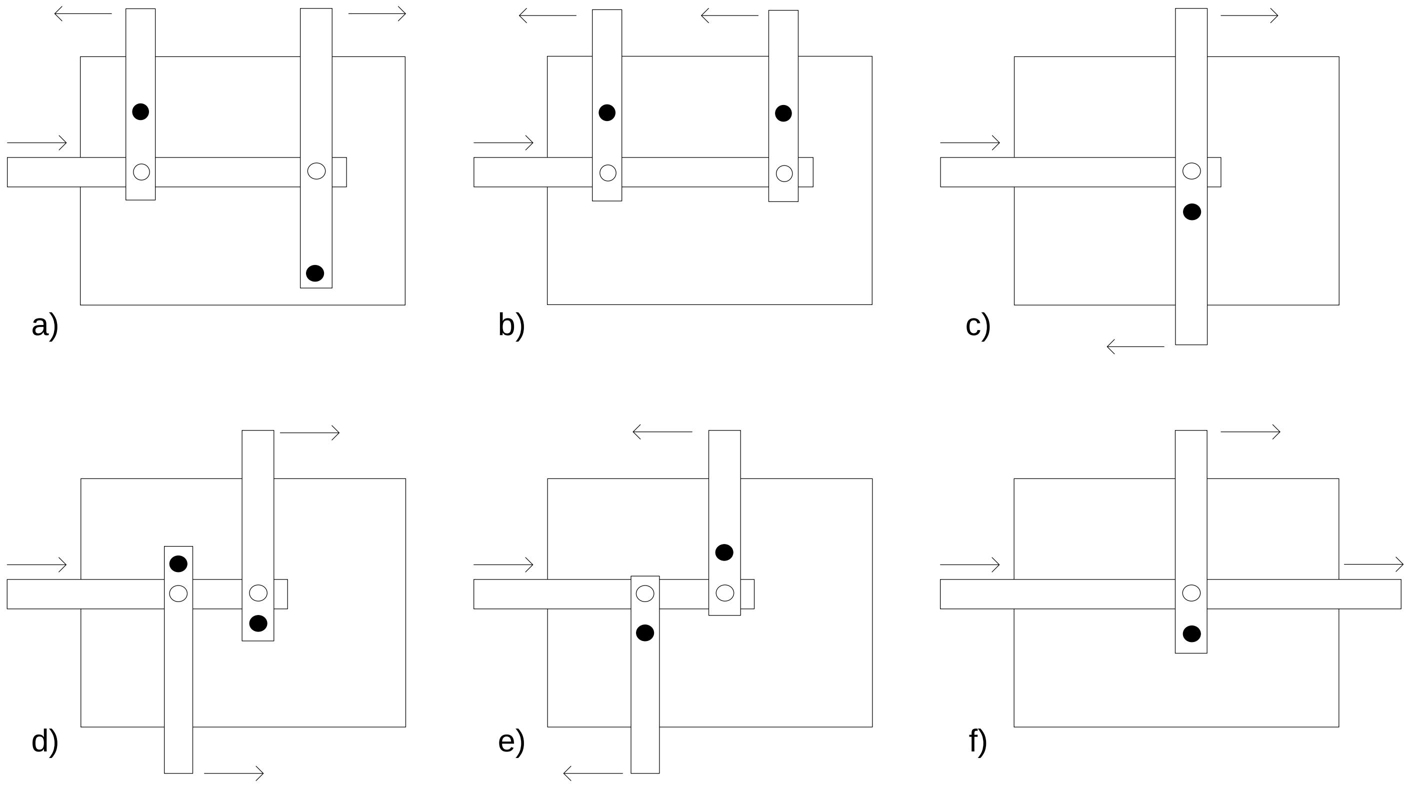


Figure 17: Solutions to Mystery Mechanisms challenges

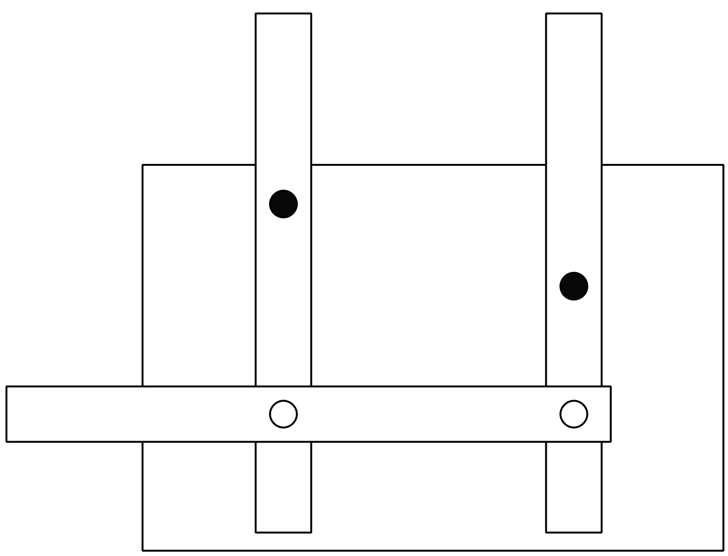
How to Make the Sample Whale-Chasing-Boat MechAnimation

This MechAnimation uses the same mechanism as the Same-Direction Windshield Wipers MechAnimation. The only difference is in the cover sheet and the templates. You will need the "Aquatic" cover, and the whale and boat templates. Follow the directions for the Same-Direction MechAnimation (see pp. 22-24) through step 4. Then:

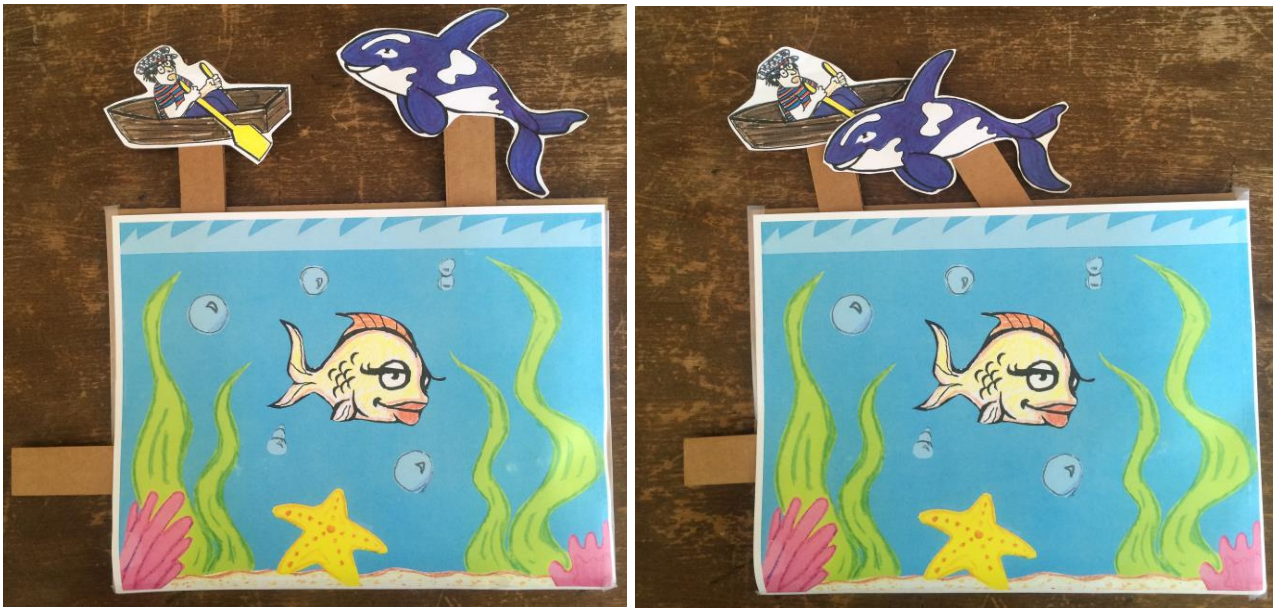
5. Tape the "Aquatic" cover over the base, making sure the strips are still free to move. Cut out the whale and the boat from the templates. Attach the boat to the output on the left and the whale to the output on the right.
6. The finished product is shown below in both positions:


How to Make the Sample Whale-Catching-Boat MechAnimation:

This is very similar to the Whale-Chasing-Boat. The only difference is in step 3, setting the locations of the fixed pivots. These pivots for this one should be placed as shown below.

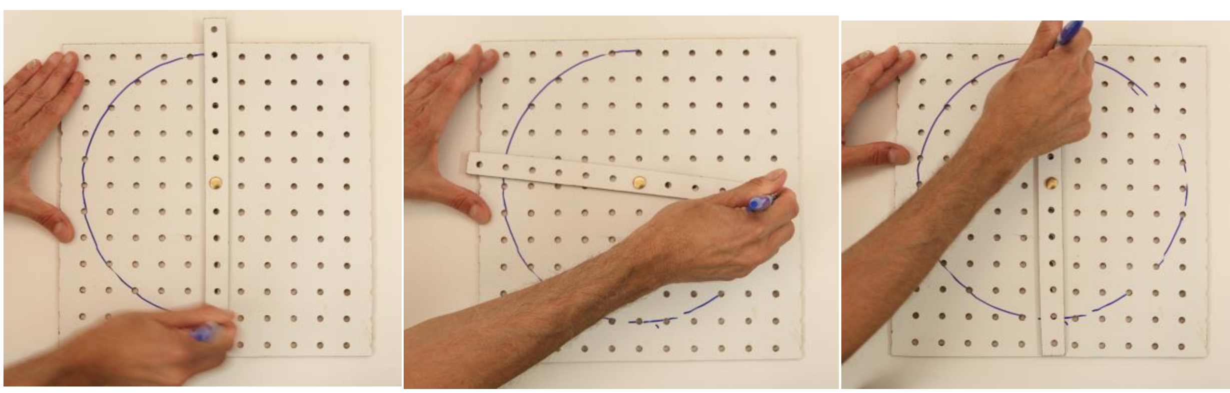


The finished product is shown below in both positions:

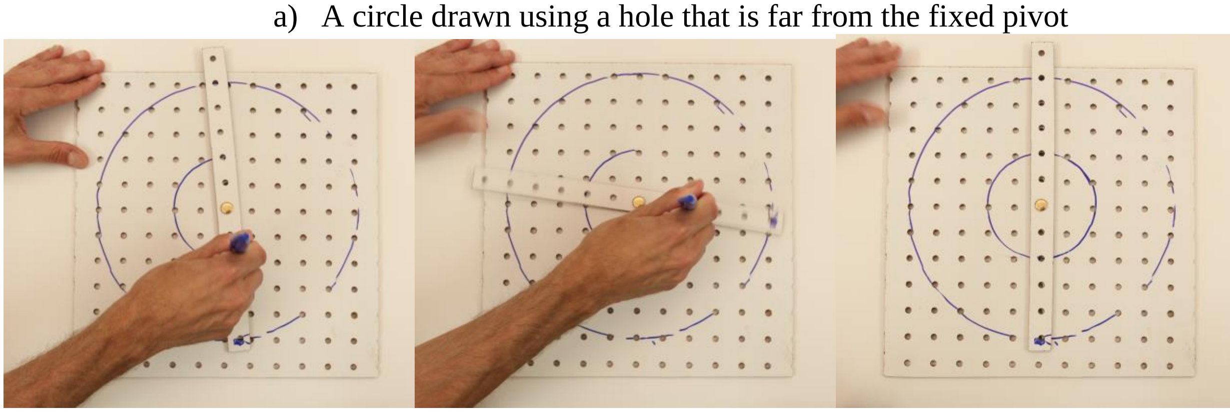


Making one output go further and faster than another

To solve this problem, think about how the circumference (length) of a circle changes, depending on its radius (distance from the center). Figure 18 shows two circles, both drawn on pegboard. In a), the circle isw drawn using a hole far from the fixed pivot, which is the center of the circle. In b), a second circle is drawn using a hole closer tto the fixed pivot. Obviously, the second circle shorter than the first! In addition, because the marker didn't have to travel as far in the same amount of time, the speed was also less in the case of the second circle, compared with the first.



a) A circle drawn using a hole that is far from the fixed pivot



b) A second circle drawn using a hole closer to the fixed pivot

Figure 18: Comparing circles drawn from different holes on a rotating arm

Something similar happens at the output of a lever. It doesn’t make a full circle, but it does follow an arc, which is part of a circle. Figure 19 shows arcs drawn at different points on a lever.

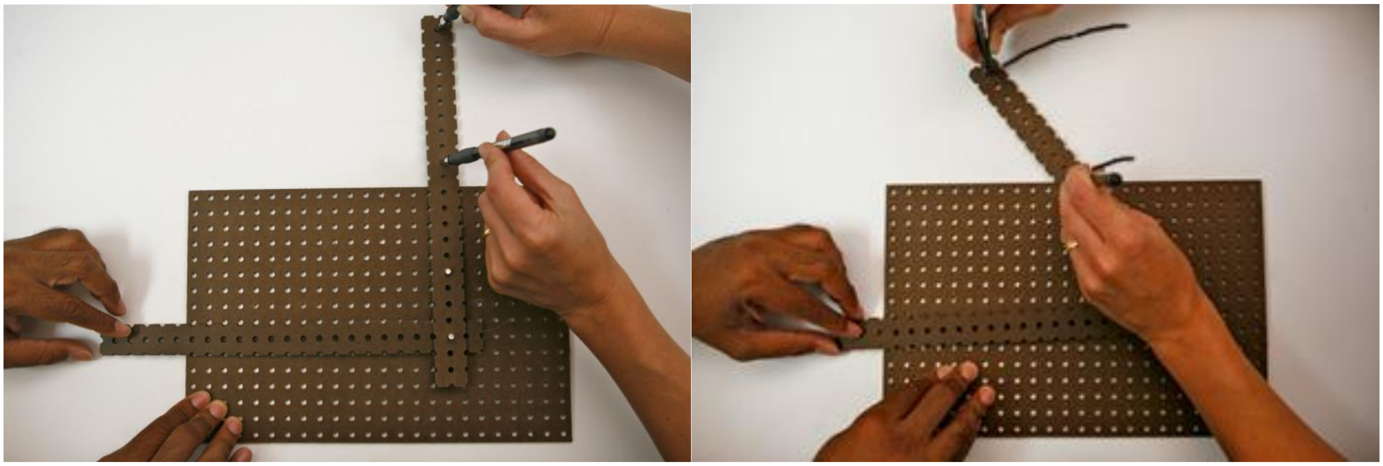


Figure 19: One person tracing two paths on a lever, while another is operating the input link

What this means is that the output of a lever will go faster and further, the greater the distance between its fixed pivot and the output itself. In the Whale-Catching-Boat MechAnimation, the whale has to move faster and further than the boat, in order to catch it. Therefore, the boat’s fixed pivot should be closer to the output – higher – than the whale’s fixed pivot. Figure 20 shows how to place the fixed pivots to make the whale (right) go faster than the boat (left):

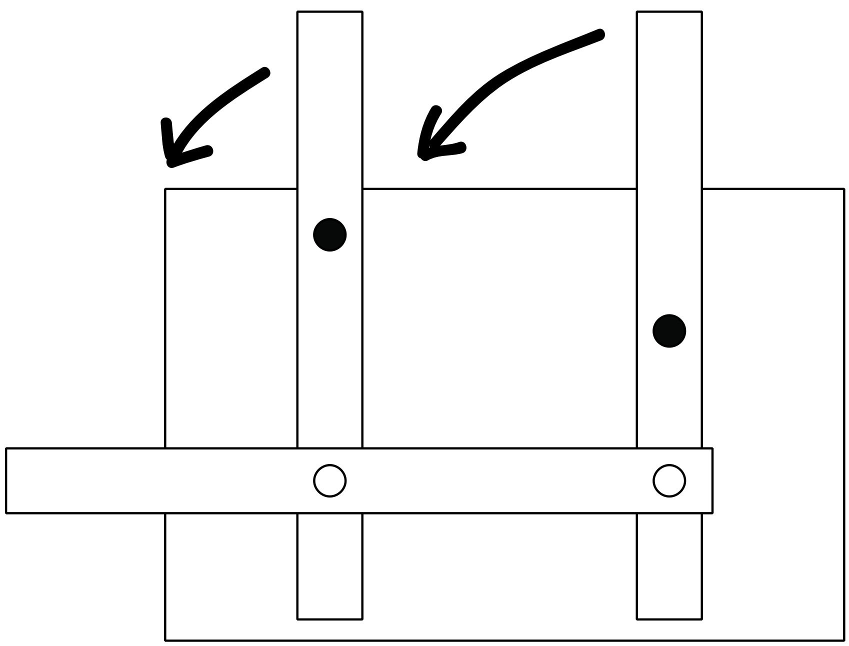


Figure 20: Diagram showing how to make the Whale-Catching-Boat MechAnimation

Materials for MechAnimations

Item	Detail	Qty.	Lessons
Pegboard, brown, holes on ½" centers	Base, 8" x 12"	30	all
	Strip, 1" x 12"	100	
Aluminum rivets	3/16" x 3/4"	200	
Brass fastener	1 ½" brass plated	400	5, 6, 10, 11
Blank cardstock	8 ½" x 11" Assorted colors,	250	
Corrugated cardboard sheet	8 ½" x 11"	70	
Corrugated cardboard strips	1" x 11", Cut long side parallel to corrugation	150	
Manufactured mechanisms	Tweezers (pack of 4)	1	7
	Tea ball	2	
	Salad Tong	2	
	Nail clippers	2	
	Egg Slicer	2	
	Hole puncher	2	
	Pliers	2	
	Clothespin	2	
Reclosable storage bags	2 gallon	30	all
Cardstock Templates with printed figures	Hammer, nail and "Tool Assortment" cover	3	1
	Butterfly, net and "Garden Scene" cover	3	1
	"Windshield" cover (2 sets)	2	8
	Whale, boat and "Aquatic" cover (2 sets)	6	9
Craft Materials			
Google eyes	assorted sizes	100	6,11
Feathers	assorted sizes & colors	100	
Foam stickers	assorted shapes & colors	100	
Pipe cleaner	assorted colors, 12″ long	60	
Cocktail umbrella	assorted colors, 4″ diam.	30	
Pom-poms	assorted sizes and colors	100	
Google eyes	assorted sizes	100	

Lesson 1: Mechanisms and Structures

Essential Question

What is a mechanism and how is it different from a structure?

Task

After viewing some sample MechAnimations, students use pegboard and pivots to create a variety of constructions, and then classify them as either mechanisms or structures.

Standards:

CCLS – ELA

Writing: Text types and purposes; Production and distribution of writing
Language: Vocabulary acquisition and use

CCLS – Math

MP2: Reason abstractly
MP7: Look for and make use of structure

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems; 8. Obtaining and evaluating information.
Crosscutting Concepts: 1. Patterns; 6. Structure and function
Disciplinary Core Ideas: PS2.A: Forces and Motion

Outcomes

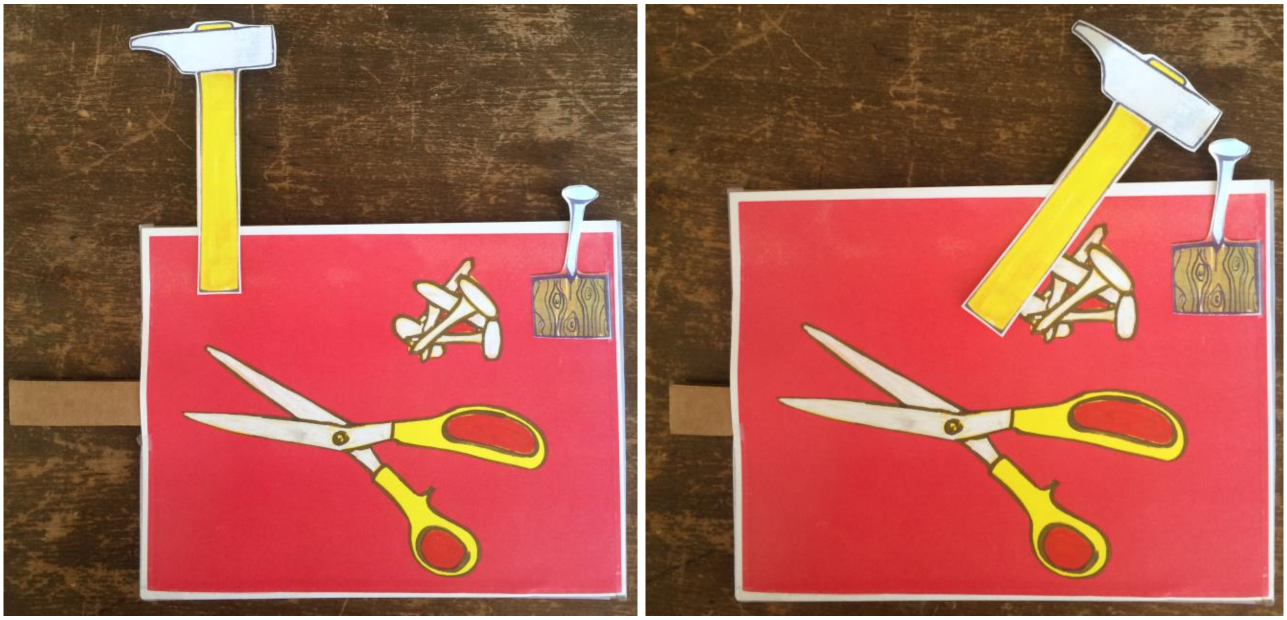
- Bases, rivets and strips can be used to make both mechanisms and structures
- A structure has no moving parts, while a mechanism has parts that can move independently from one another.
- Adding rivets can turn a mechanism into a structure, while removing rivets can convert a structure into a mechanism

Assessment

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
A. Construct mechanism and structures from bases, strips and rivets	No construction s are made	Makes a few constructions, but with little effort to explore their properties	Multiple constructions are made with limited observations about their properties	Makes multiple constructions and explains clearly how they work
B. Distinguish between a mechanism and a structure	No distinctions are made	Describes a mechanism or a structure, but not both	Identifies some mechanisms and some structures	Distinguishes accurately between mechanisms and structures
C. Explain how to convert a mechanism into a structure, and vice versa	No explanation is provided	Provides one or two examples, but does not generalize	Recognizes that structures tend to have more rivets than mechanisms	Demonstrates how to convert a structure into a mechanism and vice versa

Advance Preparation

- Photocopy Worksheets
- Construct two sample MechAnimations, and the Hammer and Nail and the Butterfly and Net. See Figure Both MechAnimations should be enclosed so students cannot see the mechanism inside. For instructions on how to make them, see pp. 11 – 13.



a) Hammer-and-Nail: Output (hammer) moves to the right as input moves to the right

b) Butterfly-and-Net: Output (net) moves to the left as input moves to the right

Figure 1: Two sample MechAnimations

Materials

- Two sample MechAnimations: Hammer and Nail and the Butterfly and Net (see Advance Preparation)
- Pegboard **bases** (one per student) and **strips** (three per student)
- R**ivets** (five per student)
- **Science Notebooks**

Procedure

1. **Demonstration of MechAnimations** (Whole class – 10 minutes): Demonstrate the two sample MechAnimations you have made: the Hammer and Nail and the Butterfly and Net. Lead a discussion about what they do:

   - *What do you notice about each one?*
   - *How are they similar and how are they different?*
   - *What would you like to make that would work like one of them?*

   Tell the students that we call these "MechAnimations," because they are mechanisms that animate a story or idea. In this unit, everybody will be making their own MechAnimations. But first, we will need to become familiar with some materials.

2. **Exploration with materials** (Individual – 20 minutes): Provide each student with a pegboard bas**e**, three pegboard strips and five rivets. Ask:

   - *In the MechAnimations I showed you, where is the base? Where are the strips?*
   - *Can you find the rivets? If not, where might they be?*

   Then encourage students to build whatever they can with these materials. Suggest that they attach the strips to the base, because that will make it easy to keep things together.

3. **Discussion of constructions** (Whole class – 10 minutes): Ask each student to show the class what he or she has made. It is likely that some of their constructions will be structures, while others will be mechanisms. Highlight these differences by asking of each one:

   - *What parts can move separately from others? Or, are all the parts stuck together so they can only move when all of them do?*

   Introduce the words **mechanism** (something that has moving parts) and **structure** (something that can only move as a whole) and write them on chart paper.

4. **Mechanisms vs. structures** (Small groups/ whole class – 10 minutes): Ask each group to sort their constructions according to the two categories, structure and mechanism. As students identify one of the constructions as a structure or a mechanism, ask:

   - *How did you decide if it is a structure or a mechanism?*

     Conduct a whole-class meeting to develop what students have learned:

   - *How can you tell if something is a mechanism or a structure?*
   - *How do you think you could change a mechanism into a structure?*
   - *How do you think you could change a structure into a mechanism?*
   - *Are the MechAnimations mechanisms or structures? How can you tell?*

   Explain that while the materials could be used to make either mechanisms or structures, from now on we will be focusing on mechanisms

Science Notebooks

- Describe what you were trying to make.
- Draw a picture showing what it looks like.
- Is it a mechanism or a structure? How can you tell?

Word Bank

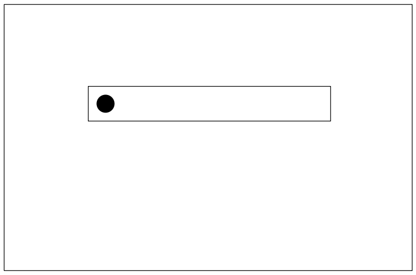
Mechanism, structure, pegboard, base, link, rivet

Name: ________________________ Date: _______________

Structure or Mechanism?

Label the Structures “S’ and the Mechanisms “M”

a)



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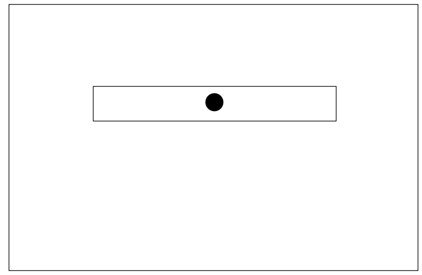

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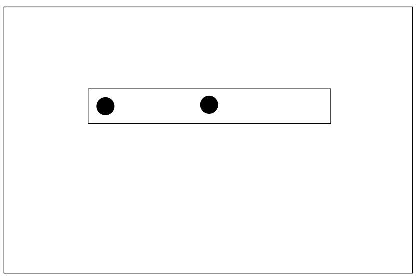

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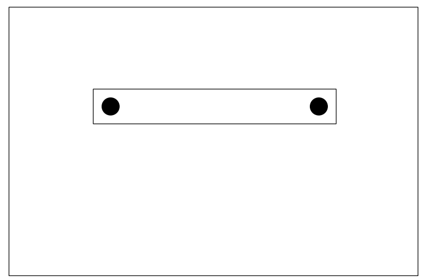

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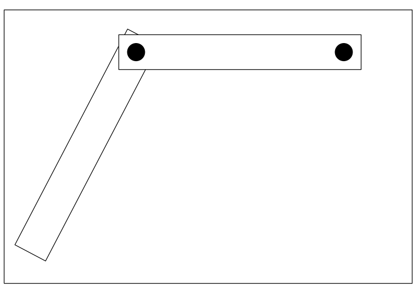

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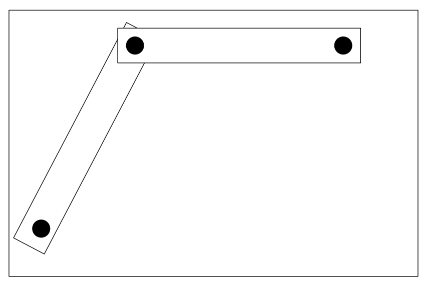

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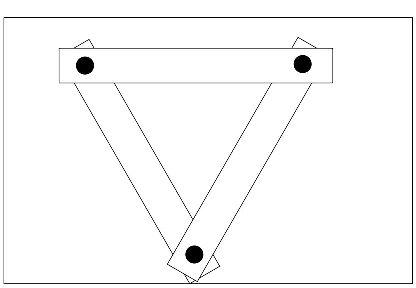

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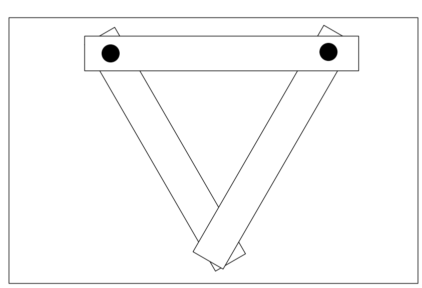


Lesson 2: The Parts of a Mechanism

Essential Question

What parts do you need to make the Hammer-and-Nail and Butterfly-and-Net mechanisms, and how do you put them together?

Task

Students use pegboard and pivots to create the mechanisms that power the two sample MechAnimations.

Standards:

CCLS – ELA

Writing: Text types and purposes; Production and distribution of writing
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

CCLS – Math

MP1: Make sense of problems

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems; 6. Designing Solutions; 8. Obtaining and evaluating information.
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction;
6. Structure and function
Disciplinary Core Ideas: PS2.A: Forces and Motion; 2. Cause and effect: mechanism and prediction

Outcomes

- Each of the sample MechAnimations has an input and an output. The input is a strip that you move back and forth. The output of the Hammer-and-Nail is the hammer, and the output of the Butterfly-and-Net is the net.
- A rivet is an example of a pivot. Pivots can be used in two ways: a fixed pivot attaches a strip to the base, allowing it to rotate, but not move back and forth. A floating pivot attaches two strips, allowing both to move back and forth, as well as to rotate.
- One strip will control another if the two strips are attached by a floating pivot. The strip that is attached to the base is called a lever, and the part of the lever that moves the figure is its output. The strip that you operate is called an input link. It is attached to the lever by a floating pivot.
- If the floating pivot is on the same side of the fixed pivot as the output, the input and output will go in the same direction, as in the Hammer-and-Nail. If the fixed pivot is between the floating pivot and the output, the input and output will go in opposite directions, as in the Butterfly-and-Net.

Assessment

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
A. Recognizes inputs and outputs, and notices the directions of motion in the sample MechAnimations	No recognition of inputs and outputs	Identifies inputs and outputs, but not directions of motion	Notices some directions of motion, but does not recognize how the two samples are different	Recognizes that in the Hammer-and-Nail, the input and output go in the same direction, while in the Butterfly-and-Net they go in opposite directions.

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
B. Identifies fixed and floating pivots and recognizes their functions	No distinctions are made	Identifies both kinds of pivot, but does not know how to use them	Constructs a working mechanism using both fixed and floating pivots	Constructs a working mechanism using both fixed and floating pivots, and explains the function of each one
C. Create pegboard mechanisms that move similarly to the samples, and explains their operation	No mechanisms are created	Makes one mechanism but not the other	Creates both mechanisms, but cannot explain the difference in their construction	Creates both mechanisms and explains why both work the way they do

Advance Preparation

- Photocopy worksheets

Materials

- Sample MechAnimations from Lesson 1: Hammer and Nail and Butterfly and Net (one per class)
- Pegboard **bases** (one per student) and **strips** (two per student)
- R**ivets** (two per student)
- **Science Notebooks**

Procedure

1. **Looking closely at mechanisms** (Whole class – 10 minutes): Again demonstrate the Hammer-and-Nail MechAnimation. Ask students to focus carefully on how it moves.
   - *What is the* **input** *to this MechAnimation (the part that I have to move to make it work)?*
   - *Where is the* **output** *of this MechAnimation (the part that tells the story when I move the input)?*
   - *When I move the input to the right, which way does the output go?*
   - *When I move the input to the left, which way does the output go?*
   - *Do the input and output move in the* **same** *or* **opposite directions***?*

   Then repeat the same exercise using the Butterfly-and-Net MechAnimation. Introduce the words **cause** and **effect** as other ways of saying **input** and **output**.
2. **The input and output of a lever** (Individual – 20 minutes): Ask students if they would like to make their own mechanisms that work like the two samples. Provide pegboard materials and rivets. Demonstrate how to make a **lever**, by using a **pivot** (rivet) to attach a strip to a base, near the middle of the strip. Push one end of the lever, and ask students to observe how the other end moves:
   - *When I push it like this, where is the* **input** *to this lever? Where is the* ***output****?*
   - *Do the input and output go in the same or opposite directions?*
   - *If I wanted the input and output to go in the same direction, where would I have to push?*

   Develop the idea that if the input and output are on the same side of the pivot, they go in the same directions, while if they are on opposite sides, they go in opposite directions. Provide time for students to make their own levers, and to explore their motions.

3. **The parts of a mechanism** (Whole class/ small groups – 20 minutes) Demonstrate the two sample MechAnimations again. Ask:

   - *How many strips does each one have inside?*
   - *What does each one do?*

   Guide students through a discussion of how the two strips in each one have to work together. The output is located on a lever, which the input strip has to be able to **control**, by moving it back and forth. A strip that does this is called an **input link**. Then challenge them to:

   - *Make your own mechanism in which one strip controls another*.

Suggested breakpoint between periods

4. **Discussion of students' mechanisms** (Whole class – 20 minutes): Ask students to share their constructions. Highlight those in which one strip does actually control another, as opposed to those where it doesn't happen. As appropriate, revisit the distinction between structures and mechanisms (see Lesson 1). Collect the issues that come up and record them on chart paper. Here are some issues that are likely to arise:

   - Some strips can't move.
   - I can't make one control another.
   - I can make one move the other by pushing, but not by pulling.
   - The end of the lever does not move in the right direction.
   - It doesn't move far enough.
   - I would like my mechanism to have more than one output, like the MechAnimation.
   - The strips can move around too much.

   As each issue comes up, ask:

   - *Did anyone else have this issue? Did anyone figure out a way to fix it?*

   Provide space for students to engage in a discussion of each issue, what made it happen and what you could do to fix it. To facilitate this discussion, review some vocabulary terms, and introduce the words **floating pivot** (which connects an input link to a lever) and **fixed pivot** (which attaches a lever to the base). A **guide** is something used to prevent the input link from moving up and down. Some ways of making a guide are to use two rivets on either side of the input link, or the put a strip of cardboard or heavy paper over the input link to keep it horizontal.

5. **Direction of motion** (Small groups/ individuals – 20 minutes): Review the previous discussion about directions of motion: in the Hammer and Nail, the input and output go in the same direction, while in the Butterfly and Net they go in opposite directions. Within each group, ask students to sort the mechanisms they have made into three categories: "Same Directions," "Opposite Directions" or "Not Sure." Then ask each student to make one of a different type from the one they made before. Ask student to complete the Worksheet and then write in their Science Notebooks.

Science Notebooks

- What materials do you think you will need to make a mechanism that works like one of the sample MechAnimations?
- What do you think you have to do to make one strip control another?
- What is different between the MechAnimations where the input and output go in the **same** direction and those where they go in **opposite** directions?
- Draw a picture of the mechanism you have made.

Word Bank

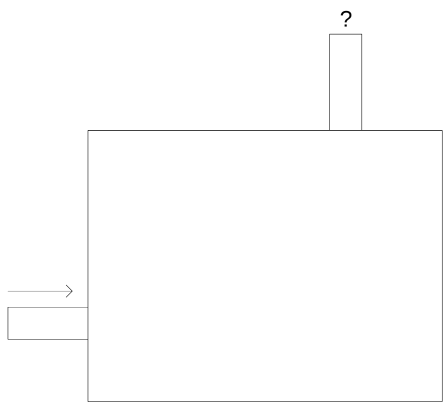
Input, Output, Pivot, Control, Fixed pivot, Floating pivot, Lever, Input link, Guide, Direction of motion, Same Opposite, Cause, Effect

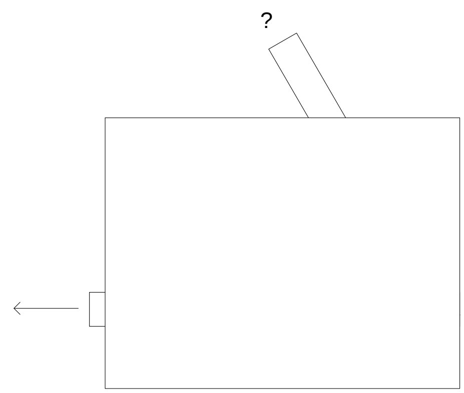
Name: ____________________ Date: ________________

MechAnimations

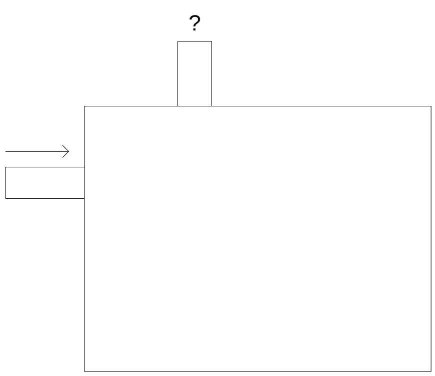
1. **Inputs and Outputs:** Write the word INPUT where you think the input is. Write the word OUTPUT where you think the output is.

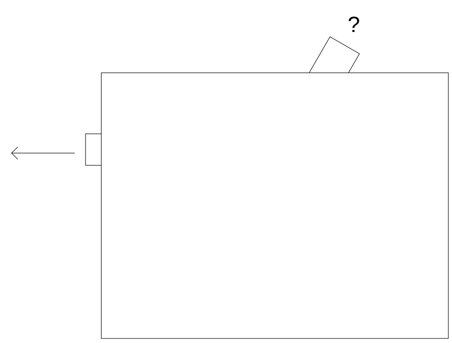
2. **Butterfly and Net**: Use an arrow to show which way the output moves for each way the input moves:





3. **Hammer-and-Nail**: Use an arrow to show which way the output moves for each way the input moves:





4. Comparing MechAnimations:

a) The <u>Butterfly-and-Net</u> input and output move in _________________ directions.

b) The <u>Hammer-and-Nail</u> input and output move in _________________ directions.

Lesson 3: Representing a Mechanism

Essential Question

How can you make a diagram of a mechanism, which someone else could use to construct it?

Task

Students learn the need for standard symbols for the parts of a mechanism, and use them to represent the mechanisms they have made.

Standards

CCLS – ELA

Writing: Text types and purposes; Presentation of knowledge and ideas
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

CCLS – Math

MP2: Reason abstractly
MP3: Construct viable arguments

NGSS

Scientific & Engineering Practices 2. Developing and using models; 4. Analyzing and interpreting data; 7. Engaging in argument from evidence; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 4. Systems and system models; 6. Structure and function

Outcomes

- Diagrams are different from drawings. A drawing tries to show what things look like, but a diagram reveals its structure.
- Diagrams use a common set of symbols, which make it easy to see how the mechanism is constructed.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
Create a mechanism diagram using standard symbols	No diagram	Minimal diagram, lacking most connections and/or parts	Most parts and connections are shown, but the distinction between fixed and floating pivots is not clear	Accurate diagram using appropriate connection points

Advance Preparation

- Photocopy worksheets
- Post a sheet of chart paper showing the Standard Mechanism Symbols (see Figure 2).

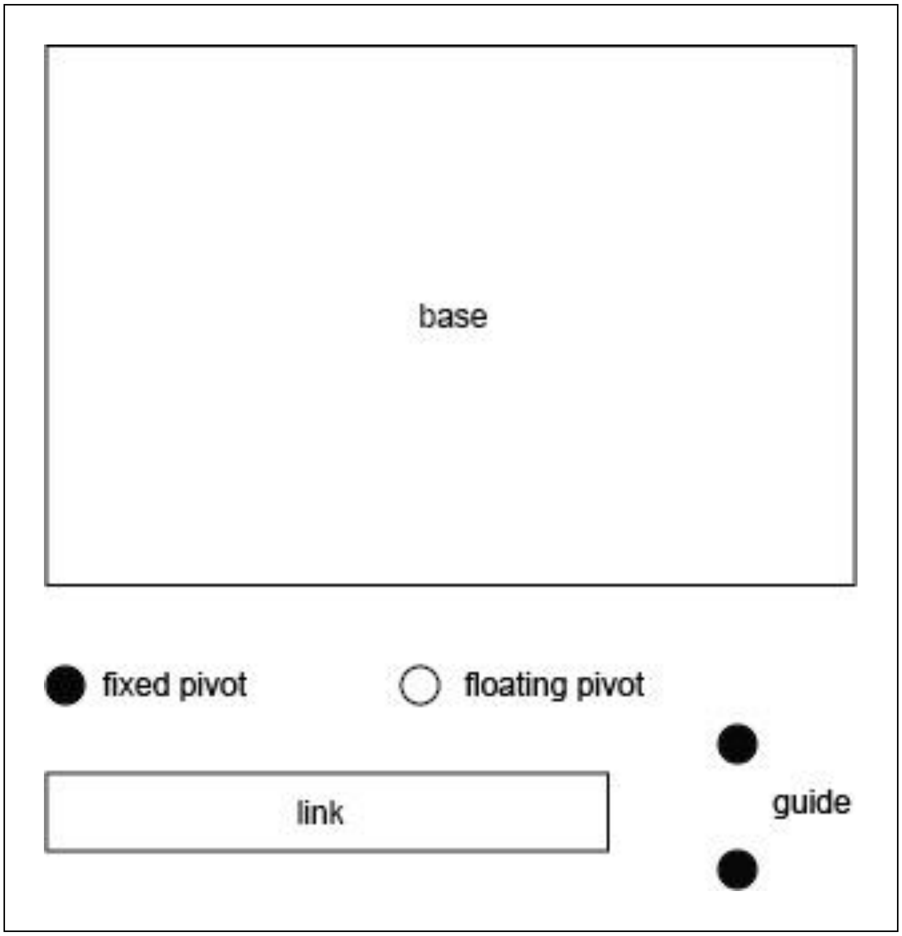


Figure 2: Chart showing standard mechanism symbols

Materials

- Students' mechanisms and drawings from Lessons 1 & 2
- Pegboard strips and bases, rivets for making new mechanisms

Procedure

1. **Gallery walk** (Whole class – 10 min.): Post the mechanism drawings students have already made, and allow everybody to examine them. Then ask for comments:
   - *What problems did you run into in making your drawing?*
   - *How are these drawings different from each other?*
   - *What problems would someone else have in using these drawings to make the actual mechanisms?*
2. **Symbols and diagrams** (Whole class – 15 min.): Elicit the observation that different students used different ways for representing the same items. If someone doesn't know what something on your drawing represents, they will not know how to make what you made. Standard **symbols** provide a way to give information in a way that people can agree on. If everyone agrees on what the symbols mean, there is no need to explain them each time. Brainstorm examples of how symbols are used. If students need prompting, offer some examples: MALE or FEMALE rest room
   - Things you can find on maps
   - Street signs (BUS STOP, HOSPITAL, NO U-TURN, DANGER)
   - How to use appliances (ON/OFF, PLAY, REWIND, FAST FORWARD, etc.)

- How to take care of clothing (for DO NOT IRON, MACHINE WASH COOL, etc.)
- NO SMOKING

Lead a discussion about how symbols work:

- *What does each of these symbols represent?*
- *How much does a symbol look like what it represents?*
- *What does the symbol for Girls' Room or Ladies' Room look like? Does the person going in there have to be wearing a dress?*

Develop the idea that a symbol is not a picture. It only has to represent an idea. If a group of people agree to use a particular symbol, then it will serve its purpose for that group. A **diagram** is different from a drawing, because it uses standard symbols to show the important parts of something, such as how to put together Lego™ or K'NEX ™, assemble furniture or appliances, etc. Ask:

- *Can you think of a situation where you used a diagram to tell you how to make or do something?*
- *How does it help to have a diagram?*

Develop the idea that a diagram tells you how to make something, including only the details that are really important. It uses symbols to represent the key parts. Ask:

- *When we represent our mechanisms, what are the important parts that we should have symbols for?*

The list should include:

- Link (which could be an input link or a lever)
- Base
- Fixed pivot
- Floating pivot
- Guide

Then introduce the chart that shows the standard symbols for these parts.

3. **Creating Mechanism Diagrams** (Individual – 20 minutes): Ask students to use these symbols to create a diagram of at least one mechanism they have made.
4. **Comparing drawings and diagrams** (Whole class – 5 minutes): Wrap up the lesson by asking students to compare the drawings they had made initially with the diagrams they have just made:

   - *Which makes it easier to share ideas, the diagram or the drawing? Why?*

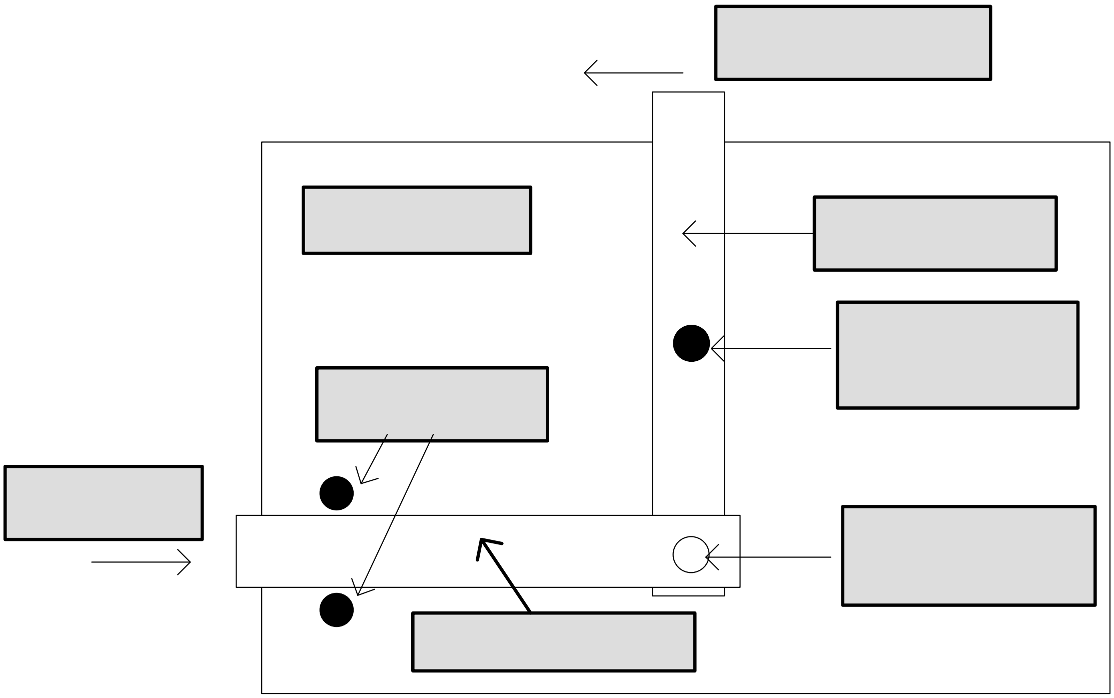
Word bank

Drawing, Diagram, Symbol

Name: ____________________ **Date:** ________________

Labeling a Diagram

Fill in the name of each item on the diagram:



Terms to choose from:
Fixed pivot
Floating pivot
Input
Output
Base
Lever
Input link
Guide

Lesson 4: Designing a Simple Mechanism that Animates a Story

Essential Question

What story could I tell using a simple mechanism, and what mechanism would I need to tell it?

Task

Write a story or idea that you could portray through a simple MechAnimation, and design the mechanism that you would need.

Standards

<u>CCLS – ELA</u>

Writing: Text types and purposes; Presentation of knowledge and ideas
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

<u>CCLS – Math</u>

MP6: Attend to precision
MP7: Look for and make use of structure
2.G1 & 3G1: Reason with shapes & their attributes

<u>NGSS</u>

Scientific & Engineering Practices 1. Asking questions and defining problems; 6. Designing solutions; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction; 6. Structure and function
Disciplinary Core Ideas: PS2.A: Forces and Motion; ETS1: Engineering Design

Outcomes

- Students develop a story or idea that could be illustrated using a mechanism
- Students use mechanism diagrams to plan the mechanisms they will use.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
A. Draw and describe the story, scene or idea	No drawing or description	Some drawing or writing; details missing, such as locations of devices <u>or</u> idea is too simple	Well-thought-out concept, clearly described via writing and drawing	Complex, innovative design
B. Design and create a diagram for each mechanism	No diagram	Diagrams are unclear, incomplete <u>and/or</u> lacking distinctions between fixed and floating pivots	Clear diagram of a basic mechanism	Accurate diagrams of a complex mechanism

Materials

- Pegboard mechanisms from previous lessons
- Additional pegboard strips and bases; rivets
- Science Notebooks

Procedure

1. **Brainstorming ideas for a MechAnimation** (Whole class -- 10 minutes): Explain to students that they will next have an opportunity to design their own MechAnimations: a mechanism that makes a story, scene or idea come alive. The ideas for these could come from a class theme, such as a neighborhood walk, a story, period of history, or science topic; or they could be entirely original. The first step is to brainstorm ideas for the story, scene or idea.
2. **Creating the story** (Individual – 20 minutes): Ask each student to **plan** his or her idea for a MechAnimation:
   - *What would you like your MechAnimation to show?*
   - *What part will be moving and what will be fixed?*
   - *Write the story and make a drawing showing the scene.*
3. **Designing the mechanism** (Individual – 20 minutes): Review the use of mechanism diagrams. Each student should **design** the mechanism that will be inside the MechAnimation they will create. Review the use of mechanism diagrams, and encourage students to develop their mechanism ideas using diagrams. Provide pegboard materials for students who would like to test out their ideas for mechanisms. Explain that the MechAnimations they make will actually be made out of cardboard. The next lesson will focus on transferring a mechanism idea from pegboard to cardboard.

<u>Science Notebook:</u>

- Describe and draw the scene you would like to create.
- Make a drawing showing what the scene will look like.
- How will you use a mechanism to make your scene come alive?

Word bank

Design, plan

Lesson 5: Exploring Materials and Using Models

Essential Question

How can I be sure my mechanism will work, before I build it into my MechAnimation?

Task

Create a pegboard model of the mechanism, and use it to create a similar mechanism in cardboard.

Standards

<u>CCLS – ELA</u>

Writing: Production and distribution of writing
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

<u>CCLS – Math</u>

MP4: Model with mathematics

<u>NGSS</u>

Scientific & Engineering Practices 2. Developing and using models; 7. Engaging in argument from evidence; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 4. Systems and system models; 6. Structure and function
Disciplinary Core Ideas: PS1.A: Properties of Matter

Outcomes

- Different materials have different properties. When two different materials are used to make similar things, each material will often be better in some ways but worse in others. This is an example of a **tradeoff**.
- A mechanism is a **system**: a collection of parts that work together, including an input and an output.
- A **model** is a way of representing a system. A model shows how the parts of a system work together, but is not the same as the real system. It may use different materials, be smaller or simpler. A diagram is a model made on paper.
- A diagram and a pegboard model of a mechanism can help you to understand and build the mechanism you will use.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
A. Identifies differences between materials, and pros and cons of each one	No observation s about materials	Identifies some differences between cardboard and pegboard, but does not gve an example of how one could be better than the other	Explains the pros and cons of both cardboard and pegboard	Explains the pros and cons of both cardboard and pegboard, and generalizes to other examples of comparison between materials
B. Identify systems and relates them to the system concept	No examples are found	Provides examples of systems, but does not explain what they have in common	Identifies a mechanism as a system, and indicates why it is a system	Identifies multiple examples of systems, explains why each one is a system

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
C. Explain how a model can be used to understand a system	No description	Identifies some models, but not their uses	Identifies both diagrams and physical pegboard constructions as possible models for a mechanism	Uses multiple examples to show how a model can be useful for understanding a system
D. Create and use a pegboard model to design a cardboard mechanism	No model	The cardboard mechanism does not reflect the model	The model is used effectively as a design tool	Uses model as design tool and identifies other examples of how model can be used

Advance Preparation

- Start a chart for listing examples of models:

System	Model	How are they similar?	How are they different?
Car	Toy car	Both have wheels, can travel	Model is smaller, has no motor, nor passengers

- Make a sample pegboard mechanism model, similar to Figure 3, below:

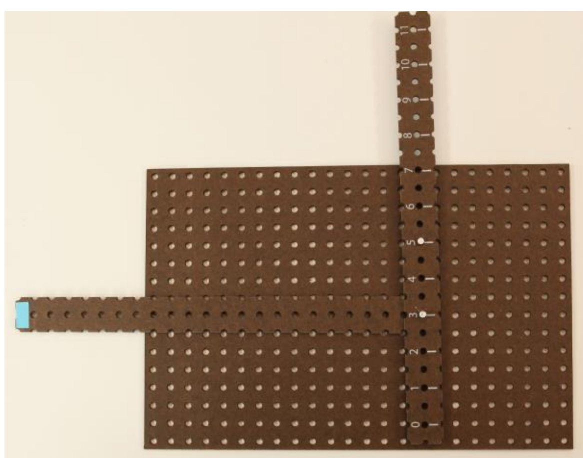


Figure 3: Sample pegboard mechanism

- Make a cardboard mechanism that works roughly like the one in Figure 3, but with the holes placed incorrectly, so the action is clearly different from that of the pegboard model

Materials

- Pegboard mechanisms from previous lessons

- Pegboard strips and bases; rivets
- MechAnimation stories and mechanism diagrams from Lesson 4
- Cardboard bases (one per student), cardboard strips (3 per student) and paper fasteners (three per student)
- Post-Its™ or small pieces of paper and glue stick

Procedure

1. **Comparing materials** (Whole class – 10 minutes): Distribute the mechanisms from previous lessons. Provide each group with some **cardboard** pieces and **paper fasteners**. Ask:

   - *How could you make mechanisms using cardboard instead of pegboard?*
   - *How are these cardboard pieces similar to the pegboard pieces? How are they different?*
   - *What would be better about mechanisms made from cardboard?*
   - *What would be better if I made them from pegboard?*

   Develop a comparison between the two sets of materials: cardboard has no holes, so you will have to make them yourself. Also, it is more **flexible** than pegboard, so a cardboard strip might **bend** when you pushed on it. However, cardboard also **costs** less, so you could keep any mechanism you made from it. This is an example of a **tradeoff**: two or more design choices, each of which is better in some ways but worse in others.

2. **What is a model and why is it useful**? (Whole class – 15 minutes): Introduce the concept of a **model**: something used to represent a **system**. A system is something that has parts that work together to achieve a goal. Every system has an input and an output. A model has some of the features of the real system, but is different in that it is simpler, smaller, made of different materials, and/or produced on paper rather than 3D. Models are useful, because they are easier to understand than the real thing, but still contain its important features. For example, a toy car is a model of a real car. It is unlike a real car in being much smaller, lacking a motor, having no room for passengers, etc., but like a real car in that it has wheels and can roll from one place to another. Ask the class for their own examples:

   - *What models can you think of?*

   For each example, ask:

   - *What system is it a model of?*
   - *How is the model <u>different</u> from the real system? How are the model and the real thing <u>similar</u>?*
   - *How could you use the model to help you understand the real system?*

   As students provide their own examples enter each one on a row of the chart you have prepared.

3. **Making pegboard models from the mechanism diagrams** (Individual – 20 minutes): Remind students of the MechAnimations they have designed in the previous lesson, and of the diagrams they used to plan their mechanisms. The next step is for them to create pegboard models from these diagrams. They will use these models to test their mechanism ideas, before creating similar mechanisms in cardboard to power their MechAnimations. Ask students to take out the diagrams they have made in Lesson 4, and provide pegboard materials and rivets for them to create the pegboard models. To see how the action will look, students can draw stick figures on Post-Its™ and attach them in appropriate places on the model to see how they will work. If Post-Its™ are not available, use small pieces of paper and attach them with glue stick.

Suggested breakpoint between periods

4. **How to use a pegboard model to make a cardboard mechanism** (Whole Class – 20 minutes): Remind students of the purpose of the pegboard models: to provide a way of trying out their mechanism ideas before making them in cardboard. Once they are satisfied with the way the models work, they are ready to transfer their mechanisms to cardboard. These will be the mechanisms that power the MechAnimations they will create in the next lesson.

   To illustrate the importance of locating the holes accurately in the cardboard, demonstrate the pegboard model you have made and then the cardboard version with inaccurately placed holes. Ask:

   - *What is similar between these two mechanisms? What is different?*
   - *Why is it important to put the holes in the same places in the cardboard as in the pegboard?*
   - *What could happen if the holes are in different places?*
   - *How do you think you could locate the holes accurately?*

   If students don't come up with a method for locating the holes in the cardboard, demonstrate how to make holes in cardboard at locations that correspond to the pivot locations in the pegboard:

   - Place the pegboard over the piece of cardboard.
   - Remove the rivet from the hole, remembering which hole it was in.
   - Push a pencil through this hole to make a hole in the cardboard below

5. **Making cardboard mechanisms** (Individual – 30 minutes): Provide time and materials for each student to create a cardboard mechanism that is similar to the pegboard model.

Word bank

Material, compare, pegboard, cardboard, flexible, bend, cost, tradeoff, paper fastener, system, model

Lesson 6: Making a Simple Mechanimation

Essential Question

How can I make my MechAnimation do what I designed it to do?

Task

Create a MechAnimation that tells a story or relates an idea

Standards

CCLS – ELA

Writing: Production and distribution of writing
Language: Vocabulary
Speaking & Listening: Comprehension and collaboration; presentation of knowledge and ideas

NGSS

Scientific & Engineering Practices 3. Planning and carrying out investigations
Crosscutting Concepts: 1. Patterns; 6. Structure and function
Disciplinary Core Ideas: PS2.A: Forces and Motion; ETS1: Engineering Design

Outcomes

- Students create their own MechAnimations
- Students develop troubleshooting strategies and techniques to address issues as they arise.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
Build, test and troubleshoot a MechAnimation	Nothing built	Parts are not working; difficulty in troubleshooting	MechAnimation works as planned; evidence of troubleshooting to make it work	Elaborate and/or multiple MechAnimations and/or assistance to other students in troubleshooting

Advance Preparation

- Prepare a Troubleshooting Chart like the one below:

Issue	Cause	Fix

Materials

- MechAnimation plans from Lesson 4
- Cardboard mechanisms from Lesson 5
- Cardboard strips and bases; Paper fasteners
- MechAnimation stories and mechanism diagrams from the previous lesson
- Craft materials
- Science Notebooks

Procedure

1. **Making MechAnimations** (Individual – 40 min.): Provide time for students to create their MechAnimations, based on the designs they have made in Lesson 4 and using the cardboard mechanisms completed in Lesson 5. As they are working, ask students to keep lists of **issues –** things that don't work. Enter each issue on a separate row of the Troubleshooting Chart you have prepared.
2. **Discussion of Troubleshooting** (Whole class – 10 minutes): Near the end of the first period, pause to help students debrief and troubleshoot. Ask:

   - *If something doesn't work the way you want it to, what should you do?*

   Develop the idea that it doesn't make sense to start over, because most of what you made is probably OK. Also, if you start over, you might just run into the same issue again! It makes much more sense to:

   - Identify the **issue** that is happening;
   - Determine the **cause** of that issue; and
   - Find a **fix** for that cause so the issue stops happening.

   In engineering, this way of addressing issues is called **troubleshooting**. Review each of the issues you have entered on the Troubleshooting Chart. For each one, ask:

   - *Did anyone else have this issue?*
   - *What did you think was causing it?*
   - *What did you do to fix it?*

   Enter the "causes" and "fixes" in the appropriate rows and columns on the Troubleshooting Chart. Leave the chart posted as a reference for other students who might encounter the same problems.

Suggested breakpoint between periods

3. **Resuming work on MechAnimations** (Individual – 40 minutes) Encourage students to refer to the Troubleshooting Chart as they continue to work on their MechAnimations.
4. **Discussion of Mechanimations** (Whole class – 10 minutes): Near the end of the period, provide an opportunity for students to demonstrate and display their work, and discuss what they have learned.

<u>Science Notebook:</u>

- Describe what you made.
- What issues came up and how did you solve them?
- How do you feel about your creation?
- What would you do differently next time?

Word Bank

Troubleshooting, issue, cause, fix

Lesson 7: Exploring Manufactured Mechanisms

Essential Question

How do ordinary utensils and tools use levers to do their jobs?

Task

Examine common objects to find out how they work

Standards

CCLS – ELA

Writing: Text types and purposes; Research to build and present knowledge
Speaking & Listening: Comprehension and collaboration; presentation of knowledge and ideas
Language: Vocabulary acquisition and use

CCLS – Math

MP2: Reason abstractly
MP6: Attend to precision
MP7: Look for and make use of structure
2.G1 & 3G1: Reason with shapes & their attributes
2.MD 1-4: Measure and estimate lengths
2. MD 9&10; 3.MD 3&4: Represent and interpret data

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems;
2. Developing and using models; 3. Planning and carrying out investigations:
4. Analyzing and interpreting data; 6. Designing Solutions; 7. Engaging in argument from evidence;
8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction;
4. Systems and system models; 6. Structure and function
Disciplinary Core Ideas: PS1.A: Properties of Matter; PS2.A: Forces and Motion; ETS1: Engineering Design

Outcomes

- People use mechanisms in their everyday lives. Every mechanism has a job that it is designed to do.
- To make a mechanism work, the user has to move its input.
- The output is where a mechanism does its job.
- Most mechanisms use levers to make it easier to move the input than the output

Assessment

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
A. Identify the job that a mechanism does	Nothing identified	Identifies the task in general terms	Identifies the tasks of several mechanisms specifically, such as "cuts," "squeezes," or "grabs"	Categorizes a variety of mechanisms by identifying the function of each one
B. Identifies the input to a mechanism	Nothing identified	Identifies the input in general terms	Demonstrates the inputs of several mechanisms	Categorizes the inputs of a variety of mechanisms according to the type of motion: line, arc or circle.

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
C. Identifies the output of a mechanism	Nothing identified	Identifies the output in general terms	Shows the location and motion of the output of a several mechanisms	Categorizes the outputs of a variety of mechanisms according to the type of motion: line, arc or circle
D. Explain how a mechanism uses levers to make work easier	No explanation	Notices the difference between input and output motions	Describes the difference between force required at the input, and force delivered at the output of at least one mechanism	Identifies the levers in a compound mechanism and shows the how the inputs and outputs of each one are related

Advance Preparation

- Collect a total of about 30 mechanisms, half of which will be supplied. Collect the rest from home and school. These could include scissors, snack food clips, salad tongs, barbecue tongs, pliers, clothes pins, can openers, nut crackers, lemon squeezers, egg slicers, garlic presses, tweezers, eyelash curlers, nail clippers, hole punchers and staple removers.
- Post chart paper for recording observations

Materials

- About 30 assorted mechanisms (see Advance Preparation)
- Science Notebooks

Procedure

1. **Exploration of mechanisms** (Small groups – 15 minutes): Provide each group with at least six mechanisms. Ask the students to look at all of them closely. Ask:
   - *What do all these objects have in common?*
2. **Features of a mechanism** (Whole class – 15 minutes): After a few minutes, conduct a whole-class meeting in which you debrief the groups. Ask each group to report only one item from their list, being careful not to repeat any items that have already been reported. Write each observation on chart paper, without commenting on it. Go around the room, soliciting one new item from each group each time, until their lists are exhausted.

   Review the chart-paper list. Using a different color marker for each one, highlight three different kinds of observations:

   - Observations about what you have to do to use them: they work by hand, you have to push or pull, you need to move them to make them work, it takes force, etc.
   - Observations about what they are used for: each one has a job to do, but these jobs may be different. Some cut, others squeeze, yet others grab, etc.
   - Observations about how they are put together: they have moving parts, there's a pin or pivot, there's a little circle holding it together, this part doesn't move but the others do, etc.

   If the chart becomes too confusing, use another sheet (or sheets) of chart paper to collect and record observations of each type. Finally, ask:

   - *How are these devices similar to the MechAnimations we have made?*
   - *How are they different?*

Elicit the observation that both the manufactured articles and the MechAnimations are **mechanisms**: each one has moving parts, an **input** (the place where you operate them) and at least one **output** (the part that does the job. They all include **pivots**, and some of the moving parts are **levers**. However, the manufactured mechanisms use different materials, they move more smoothly and don't have pictures.

3. **Looking closely at a mechanism** (Individual – 20 minutes): Introduce some new vocabulary. In the language of levers, the input is called the **effort**, because it is the place where the user puts force into the mechanism. The output is called a **load**, and a fixed pivot is called a **fulcrum**. Most levers are designed to allow a smaller amount of **force** at the input (effort) for a larger force at the output (load). Present these words by making the following chart:

General Term		Language of Levers
Input	⇔	Effort
Output	⇔	Load
Pivot	⇔	Fulcrum

Then ask each student to select one of the mechanisms on their table, make a drawing of it, and label the **effort**, the **fulcrum** and the **load**. Ask:

- *Where do you think the force is less – at the effort or the load?*
- *How can you tell?*

If necessary, model this activity by creating a large diagram on chart paper of one of the mechanisms, and labeling these three items. Ask students to think about how easy it is to punch a hole in cardboard with a hole puncher, compared with using a pencil or a pen to make the same hole. The increased amount of force at the output is called **mechanical advantage**.

Once they are done, ask a few students to present their work. If students find this too easy, you can pose any of the following challenges:

- Find a mechanism somewhere in the room, other than the ones you've look at so far. How do you know it is a mechanism? Where is its input, its output and its pivot?
- Find a mechanism in your body. How do you know it is a mechanism? Where is its input, its output and its pivot?
- Find a mechanism that has more than one lever, where the output of one is the input to another. Label each lever in a different color, and show its effort, fulcrum and load.

Science Notebook:

- Describe and draw your mechanism.
- What do you think it is used for?
- What do you have to do to use it? What happens as a result?
- How does your mechanism make work easier?
- On your drawing, label the **effort**, the **fulcrum** and the **load**. (If your mechanism has more than one lever, label the parts of each one.)

Word bank

Fulcrum, effort, load, force, simple lever, compound lever, mechanical advantage

Lesson 8: Mechanisms with Two Outputs

Essential Question

How can you combine two simple mechanisms to make two outputs move at the same time?

Task

Create a mechanism with one input that controls two outputs

Standards

<u>CCLS – ELA</u>

Writing: Text types and purposes; Research to build and present knowledge
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

<u>CCLS – Math</u>

MP2: Reason abstractly
MP4: Model with mathematics
MP7: Look for and make use of structure

<u>NGSS</u>

Scientific & Engineering Practices 1. Asking questions and defining problems; 2. Developing and using models; 4. Analyzing and interpreting data; 7. Engaging in argument from evidence; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction; 4. Systems and system models; 6. Structure and function
Disciplinary Core Ideas: PS2.A: Forces and Motion

Outcomes

- A mechanism can have two outputs instead of one. These outputs could move in the same or opposite directions.
- A complex mechanism can be understood by breaking it into simpler ones. When two outputs share the same input, it is like having two mechanisms, each with one output and one input, with the inputs forced to move together.
- Students design, make and troubleshoot a mechanism that has two outputs.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
A. Identify the difference between same- and opposite- direction mechanisms	No recognition	Notices that they are different, but does not identify how they are different	Observes that in one mechanism, the two outputs move in the same direction, while in the other, they move in opposite directions	Observes the difference and suggests how the construction of the two mechanisms might be different
B. Understand a complex mechanism by breaking it down	No recognition of how it works	Recognizes that it could be broken down, but doesn't explain how	Suggests that there are two one-output mechanisms inside a two-output mechanism	Identifies each one-output mechanisms as the <u>Hammer-and-Nail</u> or <u>Butterfly-and-Net</u>

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
C. Creates mechanisms with two outputs and two inputs	Nothing made	Creates a Windshield Wiper mechanism that does not work smoothly, or whose outputs do not move the same distance.	Creates a Windshield Wiper mechanism that works smoothly	Creates both Windshield Wiper mechanisms

Advance Preparation

- Make one of each of the two sample Windshield Wipers MechAnimations. In one, the wipers travel in the same directions, while in the other they go in opposite directions; see Figures 4 and 5. Directions for making these are on pp. 22 – 24.
- Make two pegboard models: One Butterfly-and-Net mechanism, one with the output to the right; and one Hammer-and-Nail mechanism, with the output to the left. These will be useful for illustrating how to combine two one-output mechanisms to create a two-output mechanism. See Figures 6 & 7, pp. 58-59.
- Photocopy worksheets

Materials

- Sample Windshield Wipers MechAnimations (see Advance Preparation)
- Pegboard bases, strips and rivets
- Science Notebooks

Procedure

1. **Windshield Wipers MechAnimations** (Whole class – 10 minutes): Demonstrate the Same-Direction Windshield Wipers MechAnimation several times. See Figure 4.

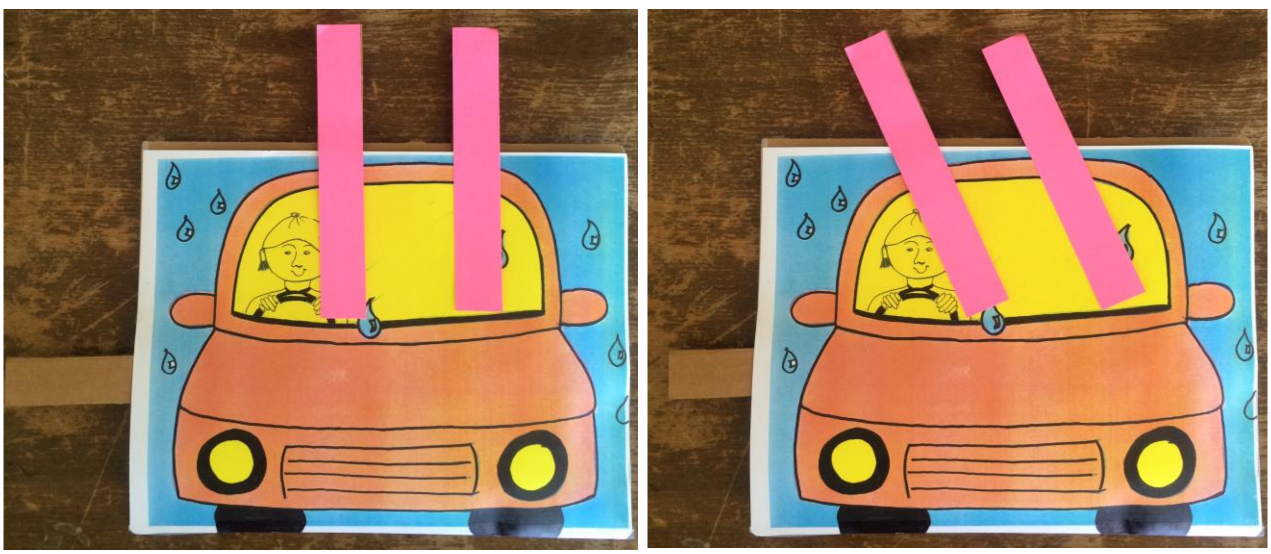


Figure 4: Windshield Wipers: both outputs move to the left when the input is moved to the right

Ask:

- *What story is it telling?*
- *Where are the inputs and outputs?*
- *How many inputs are there? How many outputs are there?*

- *What do you think is inside?*

Next show students the Opposite Direction Windshield Wipers MechAnimation. Initially, this looks the same as the previous Windshield Wipers Mechanimation. Before operating it, ask:

- *What do you think this will do?*

Then demonstrate its motion. See Figure 5.

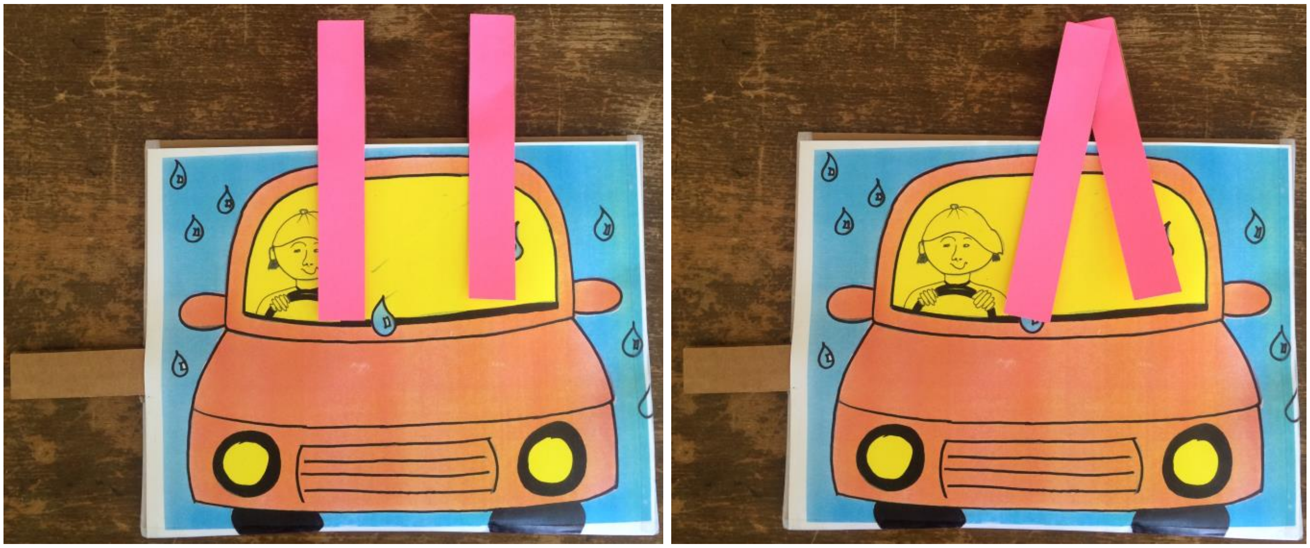


Figure 5: Windshield Wipers: outputs move together when input is pushed to the right

If students need to see both side-by-side, ask a student to work one while you work the other. Ask:

- *How are these two MechAnimations the same? How are they different?*
- *What do you think is inside each one?*

2. **Demonstration of how to combine mechanisms** (Whole class – 15 minutes): Demonstrate how a Butterfly-and -Net and a Hammer-and-Nail mechanism can be operated together to work like the Opposite-Direction Windshield Wipers. These two mechanisms are shown in Figure 6. Note that in the

   Hammer-and-Nail (left in Figure 6), the output is to the left while the Butterfly-and-Net mechanism (right in Figure 6) has its output to the right.

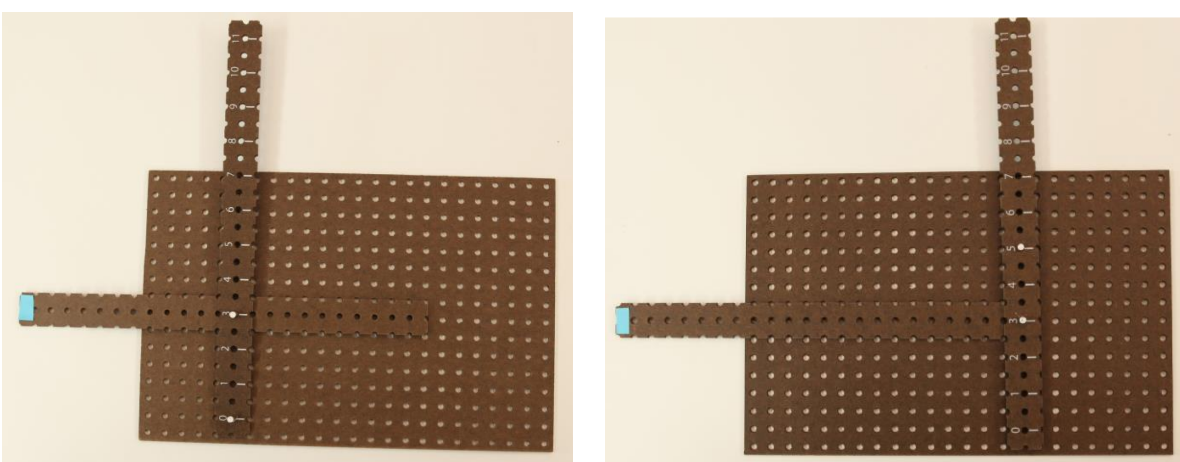


Figure 6: Hammer-and Nail mechanism (left); Butterfly-and-Net mechanism (right)

Figure 7 shows the same two mechanisms, one on top of the other, with the inputs operated together. t motion operating both. On the bottom left, the input is all the way to the left, and the outputs are apart, while on the bottom right, the input is pushed toward the right and the outputs come together.

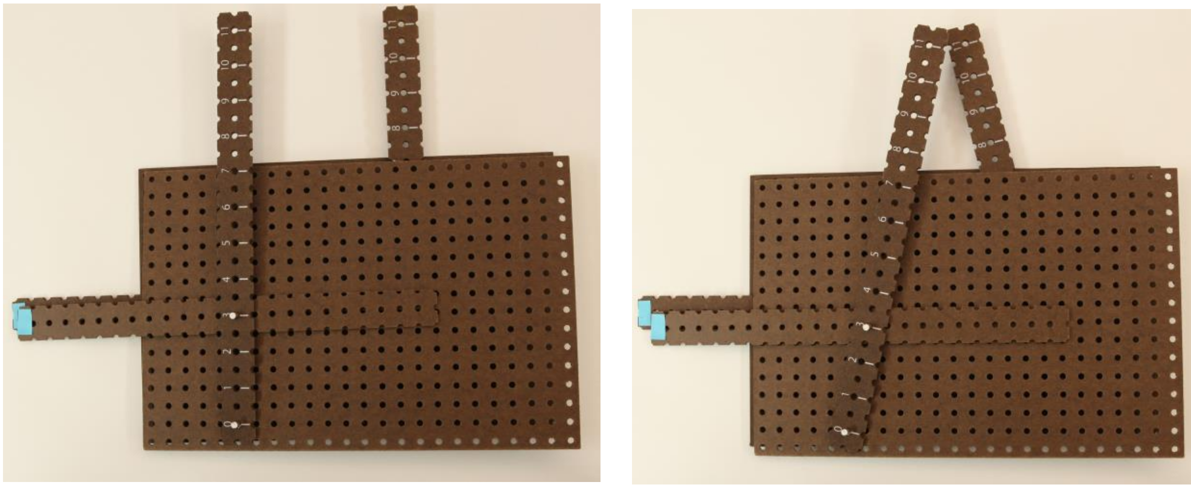


Figure 7: Place the two mechanisms from Figure 6 one on top of the other (left); then operate their inputs together to create the Opposite-Direction Windshield Wipers (right)

Ask:

- *How could you do what I just did with only one input for both outputs?*
- *How could I use this same idea to make the Same-Direction Windshield Wipers? Which two mechanisms would I have to combine?*

3. **Designing two-output mechanisms** (Small groups – 20 minutes) Ask each group to select the <u>Same-Direction</u> or <u>Opposite-Direction</u> Mechanism. Their first task is to create a diagram. Suggest they use the Same-Direction or Opposite-Direction Worksheet to help them with this task.

Suggested breakpoint between periods

4. **Making combined mechanisms** (Small groups – 40 minutes**).** Require that each group has made a diagram before beginning construction. Then provide pegboard materials for them to make pegboard models.
5. **Discussion of two-output mechanisms** (Whole class – 10 minutes)**.** Ask each group to demonstrate what they have made in front of the class, and ask the rest of the class to discuss how they work. At the end of the discussion, congratulate the class on having made a **complex system** (the mechanism with two outputs) out of two **simple systems** (each mechanism with one output). A simpler system that is now part of a more complex system is called a **subsystem.**

<u>Science Notebooks</u>

- Make a diagram of the mechanism you made.
- Describe what it does.
- What problems did you have?
- What did you do to solve them?

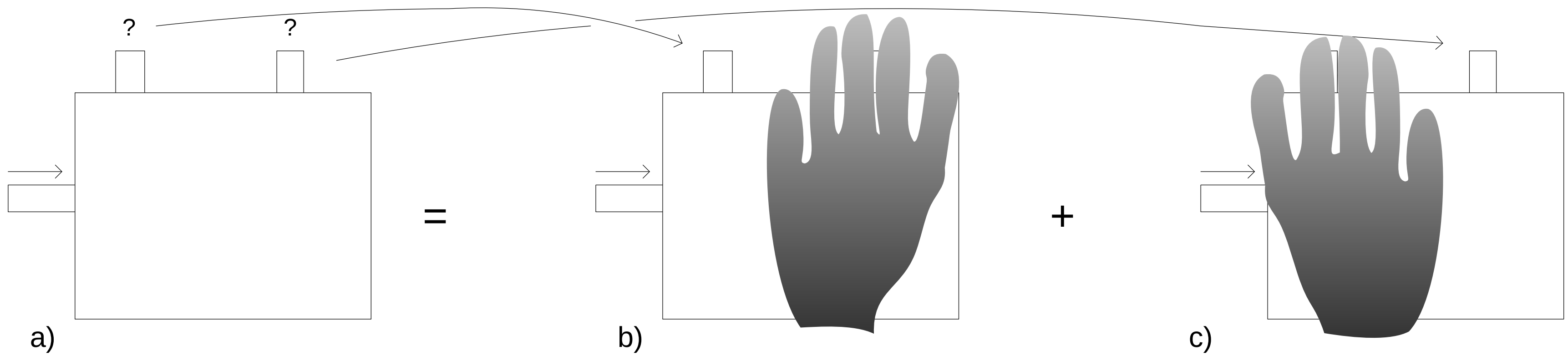
Word Bank

Complex system, simple system, subsystem

Name: ___________________________ **Date:** ___________________

<u>Same Direction</u> MechAnimation Worksheet

1. Look closely at the Windshield Wipers MechAnimation. Use arrows to show the directions of the two outputs in a), when the input moves to the right, as shown. Then copy the arrow from the left output to 1 b), and from the right output to 1 c).



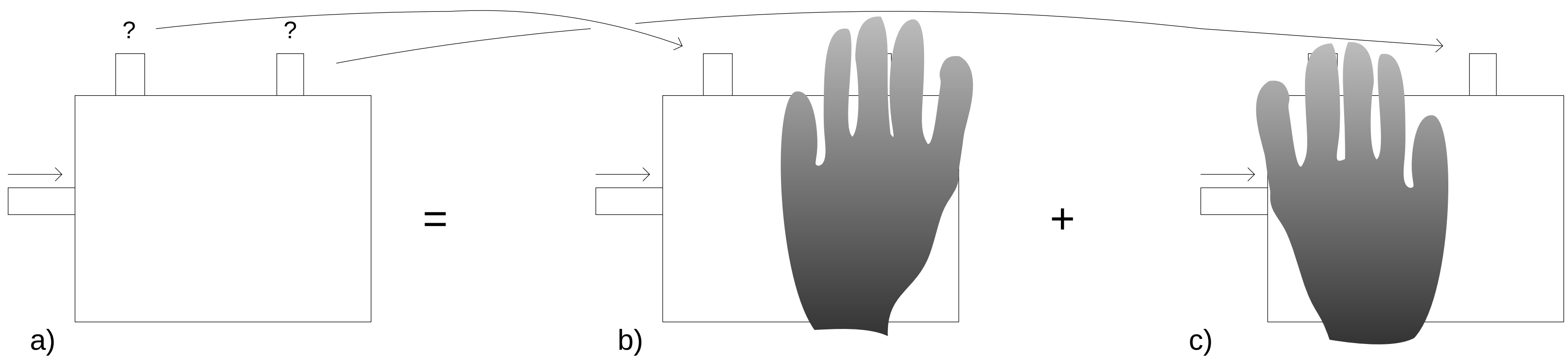
2. a) Make a diagram of a mechanism that would work like 1b):

b) Make a diagram of a mechanism that that would work like 1c):

Name: ___________________________ Date: ____________________

Opposite-Direction MechAnimation Worksheet

1. Look closely at the Opposite-Direction MechAnimation. Use arrows to show the directions of the two outputs in a), when the input moves to the right, as shown. Then copy the arrow from the left output to 1 b), and from the right output to 1 c).



2. a) Make a diagram of a mechanism would work like 1b):

b) Make a diagram of a mechanism that that would work like 1c):

Lesson 9: Controlling Speed and Distance

Essential Question

How can you make one output move faster and further than the other?

Task

Create a mechanism with one input that controls two outputs, but one output moves faster than the other

Standards

CCLS – ELA

Writing: Text types and purposes; Research to build and present knowledge
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

CCLS – Math

MP2: Reason abstractly
MP4: Model with mathematics
MP7: Look for and make use of structure
2.MD 1-4: Measure and estimate lengths
2. MD 9&10; 3.MD 3&4: Represent and interpret data

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems;
2. Developing and using models; 3. Planning and carrying out investigations:
4. Analyzing and interpreting data; 6. Designing Solutions; 7. Engaging in argument from evidence; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction;
4. Systems and system models; 6. Structure and function
Disciplinary Core Ideas: PS2.A: Forces and Motion; ETS1: Engineering Design

Outcomes

- The outputs of a mechanism can move at different speeds. If two outputs are controlled by the same input, the one that moves faster will also move further.
- Students design, make and troubleshoot a mechanism whose two outputs move different distances and at different speeds
- The distance from the fixed pivot to the output will determine how far and fast the output moves. The greater the distance, the further and faster it will move.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
A. Identify the difference between mechanisms with same-speed and different-speed outputs	No recognition	Notices that they are different, but does not identify how they are different	Observes that in one mechanism, the two outputs move the same distances or at the same speeds, while in the other, the speeds or distances are different	Observes the difference and suggests how the construction of the two mechanisms might be different

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
B. Creates a mechanism whose outputs move different distances and at different speeds	Nothing made	Creates a mechanism that does not work smoothly, or whose outputs move about the same distance.	Creates a mechanism, one of whose outputs clearly moves faster and further than the other, similar to the Whale-catching-Boat	Creates a variety of mechanisms in which various outputs move faster than others
C. Understand how the design of a mechanism affects the speed and distance traveled by an output	No recognition that the construction of a mechanism could affect speed or distance	Recognizes that the design could affect the speed or distance, but does not explain how one affects the other	Suggests that speed and distance of an output are controlled by the location of the fixed pivot	Identifies the distance between the fixed pivot and the output as the variable that controls the speed and distance

Advance Preparation

- Make one of each of the two sample Whale-and-Boat MechAnimations. In one, the whale chases the boat, but doesn't catch it, while in the other, the whale goes faster than the boat, and does catch it; see Figures 8 and 9. Directions for making these are on pp. 27-28.

Materials

- Two sample Whale-and-Boat MechAnimations (see Advance Preparation)
- Pegboard bases, strips and rivets

Procedure

1. **Whale-and-Boat MechAnimations** (Whole class – 20 minutes): Demonstrate the Whale-Chasing-Boat MechAnimation several times. See Figure 8.

Figure 6: Whale Chasing Boat: both outputs move about the same distance to the left when the input is moved to the right

Ask:

- *What story is it telling?*
- *Where are the inputs and outputs?*
- *How many inputs are there? How many outputs are there?*

Next show students the Whale-Catching-Boat MechAnimation. Initially, this looks the same as the previous Whale-Chasing-Boat MechAnimation. Before actually operating it, ask:

- *What do you think this will do?*

Then demonstrate its motion. See Figure 9.

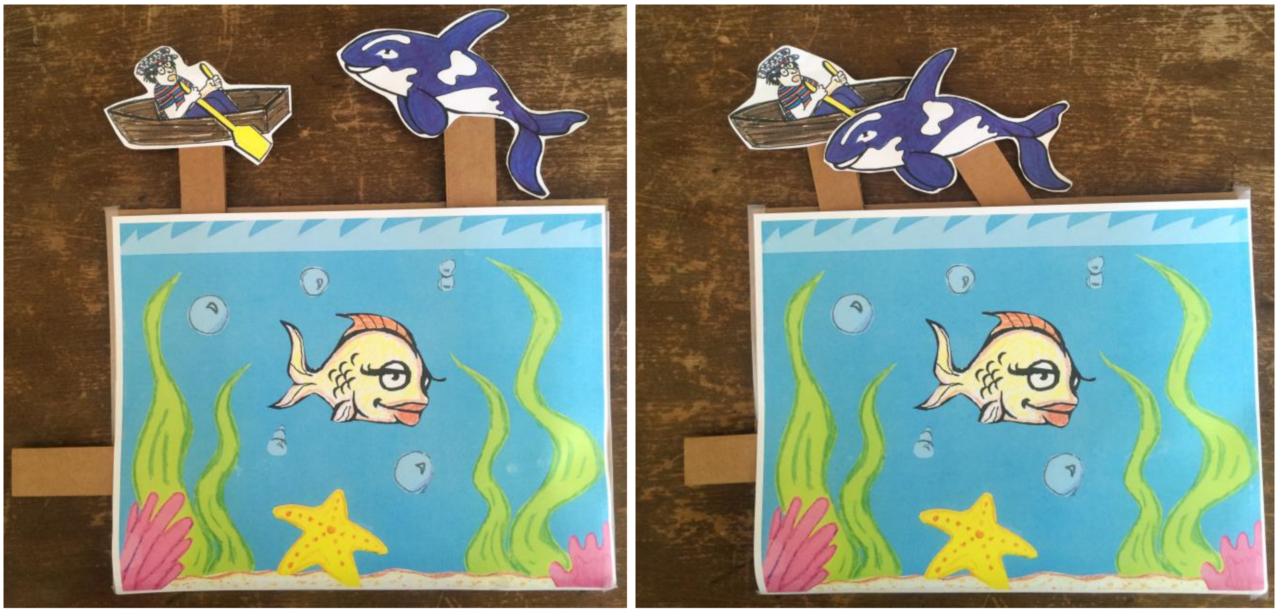


Figure 9: Windshield Wipers: outputs move together when input is pushed to the right

If students need to see both side-by-side, ask a student to work one while you work the other. Ask:

- *How are these two MechAnimations the same? How are they different?*
- *What do you think is inside each one?*

Help students notice that the in the Whale-Chasing-Boat, both outputs move the same distances, and at the same speeds. Meanwhile, in the Whale-Catching-Boat, the whale moves a greater distance and at a higher **speed** than the boat. Because speed and distance can be changed, these are **variables**. The extra speed and distance of the whale allow it to catch up with the boat! To make the MechAnimations work differently, there must be some difference in the way they are designed, there must be some difference in the design of the two MechAnimations

2. **Create a pegboard mechanism whose two outputs move different distances** (Small groups – 25 minutes) Provide each group with pegboard materials. Challenge them to make mechanisms like the Whale-Catching-Boat MechAnimations, whose two outputs move different distances in the same direction, and therefore at different speeds.
3. **Discussion and troubleshooting** (Whole class – 10 minutes) Ask each group to describe what they tried, discuss how well it worked and demonstrate what they have made. As each group demonstrates its mechanism or mechanisms, ask:

- *What do you think? Does one output go faster or further than the other?*
- *What do you think this group did?*

- *How could they improve on it?*

Suggested breakpoint between periods

4. **Resuming work on <u>Whale-Catching-Boat</u> mechanism** (Small groups – 30 min.) Review the discoveries and conclusions from the previous session. Provide additional time for students to resume work on their mechanisms. If groups have already completed the <u>Whale-Catching-Boat</u> construction, challenge them to create other mechanisms whose outputs move at different speeds. These might have more than two outputs.

5. **How to change the speed and distance** (Whole class – 20 minutes)**:** Provide time for each group to present their work. If they were successful in making one output go faster and further than the other, ask:

   - What did you have to do to make one ouput travel further than the other?
   - What variable did you change in the design to make this happen?

   Elicit the discovery that the distance between the fixed pivot (fulcrum) of a lever and the output location determines the distance and speed of the output. To make an ouput go further and faster, you have to move the fixed pivot away from the output.

<u>Science Notebooks</u>

- Make a diagram of the mechanism you made.
- What do you have do to make one output go faster than another?
- What problems did you have?
- What did you do to solve them?

Word Bank

Speed, distance, variable

Lesson 10: Designing a Complex Mechanism that Animates a Story

Essential Question

What story could I tell using a complex mechanism, with at least two outputs, and what mechanism would I need to tell it?

Task

Write a story or idea that you could portray through a complex MechAnimation, and design the mechanism that you would need.

Writing: Text types and purposes;
Speaking & Listening: Comprehension and collaboration

Standards

CCLS – ELA

Writing: Text types and purposes; Research to build and present knowledge
Speaking & Listening: Comprehension and collaboration
Language: Vocabulary acquisition and use

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems; 6. Designing solutions; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction; 6. Structure and function
Disciplinary Core Ideas: ETS1: Engineering Design

Outcomes

- Students develop a story or idea that could be illustrated using a mechanism
- Students use mechanism diagrams and pegboard models to plan the mechanisms they will use.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
A. Draw and describe the story, scene or idea	No drawing or description	Some drawing or writing; details missing, such as locations of devices or idea is too simple	Well-thought-out concept, clearly described via writing and drawing	Complex, innovative design
B. Design and create a diagram for a mechanism	No diagram	Diagrams are unclear, incomplete and/or lacking distinctions between fixed and floating pivots	Clear diagram of a basic mechanism	Accurate diagrams of a complex mechanism
C. Create and use a pegboard model to design a cardboard mechanism	No model	The cardboard mechanism does not reflect the model	The model is used effectively as a design tool	Uses model as design tool and explains how it is useful

Materials

- Pegboard mechanisms from previous lessons
- Additional pegboard strips and bases; rivets
- Science Notebooks

Procedure

1. **Brainstorming ideas for a MechAnimation** (Whole class -- 10 minutes): Explain to students that they will next have an opportunity to design complex MechAnimations, using what they have learned about combining mechanisms and controlling speed and distance. Their mechanisms should have at least two outputs. The ideas for these could come from an existing class theme, such as a neighborhood walk, a story, period of history, or science topic; or they could be entirely original. Lead a brainstorming session to come up with ideas for how these complex mechanisms could be used to tell a story or represent an idea.
2. **Creating the story** (Individual – 20 minutes): Ask each student to **plan** his or her idea for a MechAnimation:
   - *What would you like your MechAnimation to show?*
   - *What part will be moving and what will be fixed?*
   - *Write the story and make a drawing showing the scene.*
3. **Designing the mechanism** (Individual – 20 minutes): Review the use of mechanism diagrams. Each student should **design** the mechanism that will be inside the MechAnimation they will create. Review the use of mechanism diagrams, and encourage students to develop their mechanism ideas using diagrams. Then they should create pegboard models from the diagrams.

<u>Science Notebook:</u>

- Describe and draw the scene you would like to create.
- Make a drawing showing what the scene will look like.
- How will you use a mechanism to make your scene come alive?

Lesson 11: Making a Complex Mechanimation

Essential Question

How can I make my complex MechAnimation do what I designed it to do?

Task

Create a complex MechAnimation that tells a story or relates an idea

Writing:

Standards

CCLS – ELA

Writing: Text types and purposes; Production and distribution of writing; Research to build and present knowledge

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems; 6. Designing solutions; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction; 6. Structure and function
Disciplinary Core Ideas: ETS1: Engineering Design

Outcomes

- Students develop troubleshooting strategies and techniques to address issues as they arise.

Assessment

Objective:	**Below (1)**	**Approaching (2)**	**Proficient (3)**	**Advanced (4)**
Build, test and troubleshoot a MechAnimation	Nothing built	Parts are not working; difficulty in troubleshooting	MechAnimation works as planned; evidence of troubleshooting to make it work	Elaborate and/or multiple MechAnimations and/or assistance to other students in troubleshooting

Advance Preparation

- Prepare a Troubleshooting Chart like the one below:

Issue	Cause	Fix

Materials

- MechAnimation plans from Lesson 4
- Cardboard mechanisms from Lesson 5
- Cardboard strips and bases; Paper fasteners
- MechAnimation stories and mechanism diagrams from the previous lesson
- Craft materials

Procedure

1. **Making MechAnimations** (Individual – 40 min.): Provide time for students to create their MechAnimations, based on the designs they have made in Lesson 4 and using the cardboard mechanisms completed in Lesson 5. As they are working, ask students to keep lists of issues – things that don't work. Enter each issue on a separate row of the Troubleshooting Chart you have prepared.
2. **Discussion of Troubleshooting** (Whole class – 10 minutes): Near the end of the first period, pause to help students debrief and troubleshoot. Review the troubleshooting techniques from Lesson 6.

   Enter the "causes" and "fixes" in the appropriate rows and columns on the Troubleshooting Chart. Leave the chart posted as a reference for other students who might encounter the same problems.

Suggested breakpoint between periods

3. **Resuming work on MechAnimations** (Individual – 40 minutes) Encourage students to refer to the Troubleshooting Chart as they continue to work on their MechAnimations.
4. **Discussion of Mechanimations** (Whole class – 10 minutes): Near the end of the period, provide an opportunity for students to demonstrate and display their work, and discuss what they have learned.

<u>Science Notebook:</u>

- Describe what you made.
- What issues came up and how did you solve them?
- How do you feel about your creation?
- What would you do differently next time?

Lesson 12: Present your ElectroCity

Essential Question

How can others find out about what you did and what you learned from making a MechAnimation

Task

Present your MechAnimation to an audience

Standards

CCLS -- ELA

Speaking & Listening: Presentation of knowledge and ideas
Language: Vocabulary acquisition and use

NGSS

Scientific & Engineering Practices 1. Asking questions and defining problems; 6. Designing solutions; 8. Obtaining, evaluating and communicating information
Crosscutting Concepts: 1. Patterns; 2. Cause and effect: mechanism and prediction; 6. Structure and function
Disciplinary Core Ideas: ETS1: Engineering Design

Advance Preparation

- Prepare space and invite audience for presentations

Materials

- MechAnimations completed in Lesson 11

Outcome

Communicating information and ideas is a major part of developing new knowledge

Assessment

Objective:	Below (1)	Approaching (2)	Proficient (3)	Advanced (4)
A. Present a MechAnimation to an audience	No presentation	Presentation is unclear or incomplete; can't articulating how it works or what troubleshooting was done	Demonstration of MechAnimation including description of how it works and/or troubleshooting that was done	Presentation of all aspects of design, including why it was selected, how it works, troubleshooting and how it could be improved

Procedure

1. Presenting ElectroCities (Whole class – 50 min.) This is the culminating lesson, where students will present their final products to an audience. The display could take one or more of several forms:
   - **Formal presentation**: Each student shows his or her MechAnimation to an audience and explains what he or she did to make it.
   - **Museum**: Students create a display on tables, where visitors can view the MechAnimations and try them out for themselves

- **Invention Convention**: Like a Science Fair, visitors come to view the MechAnimations, test them out and talk with the students who made them.
- **Puppet show**: MechAnimations become the props for a dramatic puppet show.

Glossary

Base: A stationary platform to which the moving parts are attached.

Bend: Cause something to curve that was originally straight t

Cardboard: A paper material that is reinforced by adding layers

Cause: What makes something else happen or go wrong

Compare: Look at two things together and look for similarities and differences

Complex system: A system that can be subdivided into smaller units, each of which could be a system by itself.

Control: Part of a system that something else happen

Cost: How much you have to pay for something

Design: The way something is constructed**;** a detailed plan for making it, usually including a diagram

Diagram: A 2D representation that shows only the most important features of something.

Direction of motion: Path along which something travels; often indicated by drawing an arrow.

Distance: How far it is from one place to another

Drawing: A 2D representation that shows as much information about something `as possible

Effect: What happens as a result of a cause

Effort: Another word for input, used with levers.

Fix: An action that solves an issue by removing its cause

Fixed pivot: A pivot that attaches a lever to the base; also called a fulcrum.

Flexible

Floating pivot: A pivot that attaches one link to another, but neither to the base, such as a pivot connecting an input link to a lever.

Force: How hard you need to push or pull something to make it move

Fulcrum: A pivot that attaches a lever to another part, usually a base.

Guide: A part of the base structure added to restrict the motion of an input link or an output link.

Input link: A link used to control a lever.

Input: The action you have to take to operate a system, or the part of a system that the user operates

Issue: Something that goes wrong with a system

Lever: A link that is attached to the base by a fixed pivot.

Load: Another word for output, used with levers.

Material: What something is made of

Mechanical advantage: The amount by which the effort force of a lever is increased at the load

Mechanism: A device that has moving parts

Model: A representation of system that captures its most essential features, while leaving out details that are not important.

Output: The part of a system that does the job the system is intended for; the result of applying an input to a system.

Paper fastener: A brass or steel pin with flexible legs used to join sheets of paper

Pegboard: A stiff sheet of material with holes punched in a regular pattern

Pivot: A device that connects two parts, allowing one of them to rotate.

Plan: Create an idea for what you will make and how you will make it

Simple system: A system that cannot be broken into smaller subsystems.

Speed: How fast something moves

Structure: Something that has no moving parts

Subsystem: A part of a larger system, which could itself be a system, because it has an input, an output and something that transforms the input into the output.

Symbol: A small image that represents an idea, action or object.

System: A collection of interconnected parts that work together and includes an input and an output.

Tradeoffs: Alternative choices in design, such as whether to select a material that is stiffer or one that is cheaper.

Troubleshooting: Identifying an issue and its cause, in order to fix it

Variable: A property that changes in the course of an experiment