

Introducing Simple & Powered Machines Curriculum Pack

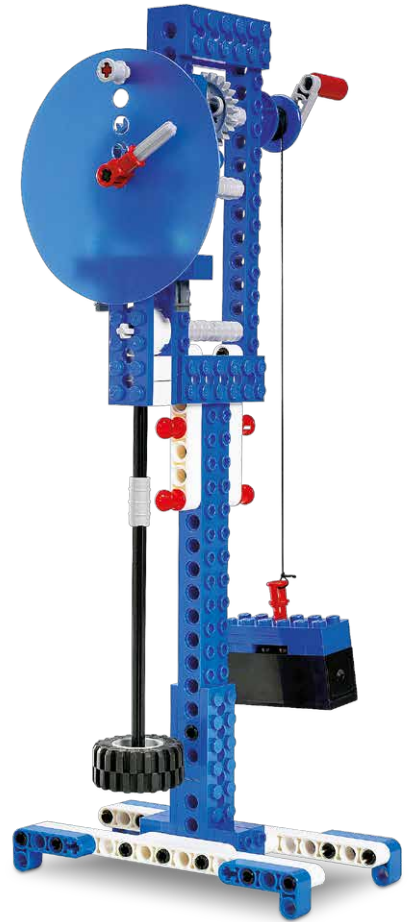




Table of Contents

1. Introduction	3
2. Curriculum	10
3. Principle Models	
Simple Machines	14
Mechanisms	58
Structures	82
4. Activities	
Sweeper	88
Fishing Rod	98
Freewheeling	108
The Hammer	118
Trundle Wheel	128
Letter Balance	138
Click-Clock	148
Windmill	158
Land Yacht	168
Flywheeler	178
Power Car	188
Dragster	198
The Walker	208
Dogbot	218
5. Problem-Solving Activities	
Uphill Struggle	228
The Magic Lock	235
Stamping Letters	242
Beaten	249
The Lifter	256
The Bat	263
6. Glossary	270
7. LEGO® Element Survey	276

Introduction

LEGO® Education is pleased to bring you 'Introducing Simple & Powered Machines'.

Who is it for?

This material is designed for use with students in grades six through eight. Working in pairs, students of any academic background can build, investigate, and learn from the models and activities included in this curriculum pack.

Please refer to the Next Generation Science Standards (NGSS) and the Common Core State Standards grids in the 'Curriculum' section of this curriculum pack to see which activities match your current teaching program.

What is it for?

The 'Introducing Simple & Powered Machines' curriculum pack enables students to work as young scientists, engineers, and designers providing them with settings, tools and activities that promote engineering design, science and mathematics.

Using our curriculum pack students are encouraged to involve themselves in real world investigations and problem-solving. They make assumptions and predictions. They design and make models and then observe the behavior of these models; they reflect and re-design, and then record and present their findings.

The 'Introducing Simple & Powered Machines' curriculum pack enables you to partially cover the following Crosscutting Concepts and overall Science and Engineering Practices, which have been set forth in the NGSS.

Science and Engineering Practices:

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Crosscutting Concepts:

- Patterns
- Cause and Effect (Mechanism and explanation)
- Scale, Proportion, and Quantity
- Systems and System Models
- Energy and Matter (Flows, cycles, and conservation)
- Structure and Function
- Stability and Change



What is in it?

The 9686 Brick Set

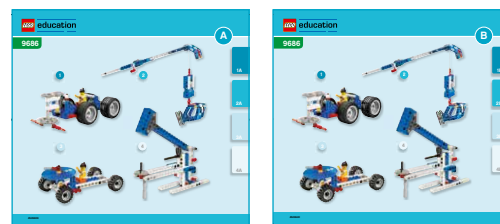
The set has 396 elements, including a motor, and building instructions booklets for 14 activity models and for 37 principle models – all in full color. Some of the building instructions booklets are intended for use with other LEGO® Education curriculum packs.

Included is a sorting tray and accompanying element overview showing all the different elements in the building set. Everything is stored in a sturdy blue storage box with a transparent lid.



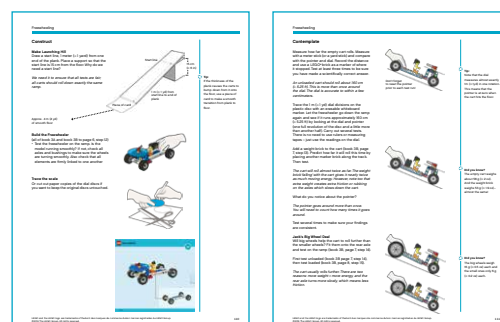
Building Instructions Booklets

For each of the activity models there are two building instructions, a booklet A and B. The building instructions are designed for two separate building processes, each building only half a model. By combining the two sub-assemblies, students work together to create a single, sophisticated and powerful model.



Teacher's Notes

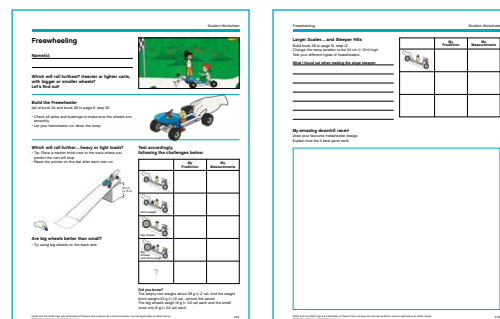
In the Teacher's Notes you will find all the information, tips and clues you need to set up a lesson. Each model the students build has specific key learning focus areas, vocabulary, questions, and answers, and further ideas for investigations.



Student Worksheets

Each student worksheet guides students to predict, try out, measure and record data, change the models to compare and contrast findings, and draw conclusions.

Let the students work in pairs, predict and test their predictions at least three times to be confident that their results are reliable. Then they record their main data accordingly. At the end of each activity, the students are challenged to design and draw a device that applies the major concepts they have just explored.



Assessments

Three different assessment materials are provided for all fourteen of the activities and the six problem-solving activities. These materials define clear learning goals before the students start each activity and motivate the students to challenge themselves throughout the learning process. You can also use these materials to assess your students' development in different learning areas.

Student Worksheets

The student worksheets should be used to record each student's work throughout each activity. These worksheets are an easy-to-use assessment tool that will give you a clear picture of each student's level and achievement during each activity. They can also comprise a valuable part of the students' log books.

Rubrics

1. Activity Assessment

This rubric page can help students to evaluate their activity work according to learning goals based on two science-related NGSS Practices and one theme from the NGSS Crosscutting Concepts.

2. Problem-Solving Assessment

This rubric can help students to evaluate their problem-solving work according to the engineering-related learning goals from the NGSS and learning objectives that are prominent in both the Common Core State Standards and 21st century skill set, specifically:

- How well did their design meet the requirements of the design brief?
- How creative was their solution?
- How well did their team work together?

Each rubric includes four levels: Bronze, Silver, Gold, and Platinum. The intention of the rubrics is to help students reflect on what they have done well in relation to the learning goals and what they might have done better. Students can write comments or questions in the 'Notes' section of each rubric.

Students should mark the rubric. If you prefer to emphasize formative assessment, ask the students to set their learning goals before they start each activity and to record the dates that correspond to their completion of each level.

You can also use the rubrics as a tool in your own evaluation of your students' work by marking a grade in the appropriate column and writing optional comments in the 'Notes' section.

Observation Checklist

If a more science and engineering practices based approach to assessment is required in the problem-solving activities, you can use the Observation Checklist provided in the Teacher's Notes to record your students' grades.

You can either use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or use other assessment criteria that are relevant to your school context.

Where can I find the assessment materials?

You can find the assessment materials in the Teacher's Notes for each of the activities and problem-solving activities.



The image shows a screenshot of the LEGO Education curriculum grid. It is a table with multiple columns and rows, detailing the curriculum for different levels of proficiency. The table is titled 'Curriculum Grid' and includes a header row with 'LEGO education' and 'Curriculum Grid'. The table is organized into sections for different subjects and levels of proficiency, with rows representing specific learning objectives and columns representing different levels of achievement.

Three Levels of Progression

The 'Introducing with Simple and Powered Machines' curriculum pack consists of thirty-eight principle models, fourteen activities, and six problem-solving activities. Each of these three components represents one level of progression, and each is described in more detail below.

Principle Models

The principle models let students experience the mechanical and structural principles normally hidden away inside everyday machines and structures. The many easy-to-build models each present a hands-on demonstration of one of the concepts of simple machines, mechanisms and structures in a clear, straight-forward manner.

The principle models are a pathway for students to understand and integrate mechanical and structural principles applied in their own models.

Activities

The fourteen activities allow students to apply and develop their knowledge of science and engineering design. These activities create a positive learning environment and offer a complete scientific learning process in which students are able to make predictions, build models, run tests, record data, make comparisons, and improve their models in order to create a better solution.

These fourteen activities connect with the concepts introduced by the principle models and help students to prepare for the increasingly difficult challenges they will meet in the problem-solving activities.

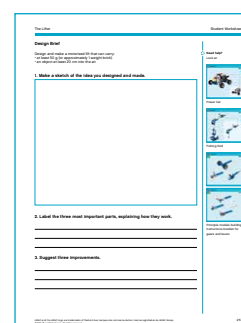
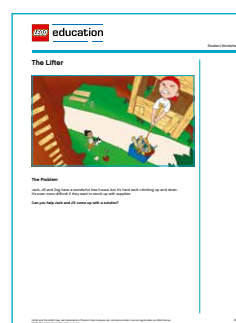
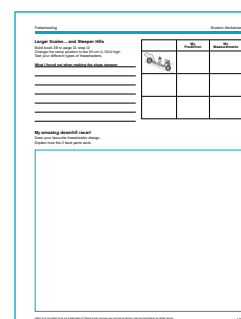
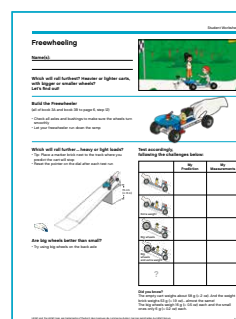
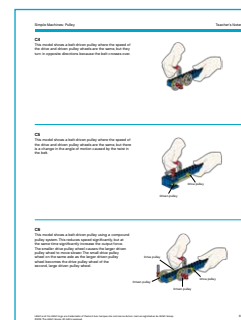
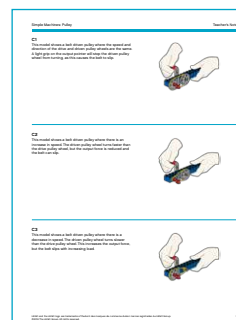
Problem-Solving Activities

The six problem-solving activities all feature real-life problems that can be solved in several ways. Students will be able to test and integrate more than just one principle at a time.

The problem descriptions and the closely-defined design briefs are provided in the student worksheets. Descriptions of learning focus areas, materials needed, extra challenges and how to progress can be found in the Teacher's Notes.

The Teacher's Notes for each challenge provide tips on what and how to measure while at the same time carrying out fair testing of the solutions.

As additional support we have included suggested solutions to the problems posed. Use these as 'tips and tricks', or print them and hang them as posters as inspiration for the students. The suggested problem-solving model solutions are only meant as guiding principles for any workable solution the students will come up with themselves.



Classroom Management Tips

For Your First LEGO® Education Activity, and Beyond

1. Before Class

- Open one of the LEGO® brick sets and sort the bricks by following the sorting suggestion on the back of the top card.
- Label the boxes so that you can recognize which box belongs to which student(s).
- Download the curriculum pack from the URL that is printed on the lid of each set.
- Try to complete the activity using the Student Worksheets.

2. During Class

- Let the students sort their LEGO brick sets at the beginning of the first lesson.
- Have the students use the lid of their set as a working tray.
- Use a jar to collect stray pieces.
- Make adjustments in order to challenge the students who are ready to improve and develop new skills.
- Allow time for students to use the self-assessment rubric when they are done with the activity.

3. After Class

- Plan to stop the lesson with enough time to allow the students to tidy up.
- If you did not finish the activity, store the LEGO sets and the models so that they are ready for the next lesson.
- Evaluate the lesson.
- Book a LEGO Education training session if you need further inspiration.

How much time do I need?

A 90-minute class period is ideal to be able to explore, build, and test in depth all the extension ideas built into the material and for the students to make any creative variations of their own.

How do I handle the building instructions booklets?

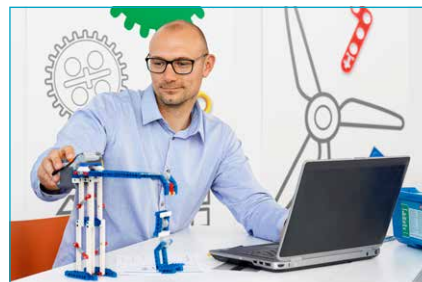
For easy classroom management we suggest storing the building instructions booklets in separate plastic folders in binders so that they are at hand and ready to use at the beginning of each lesson.

You can also ask your students to download the building instructions booklets from the URL that is printed on the lid of each set, and save them to their devices.

What's needed in my classroom?

Tables may be pushed aside to let models roll across a smooth floor. A desk fan may be needed to make a breeze, hair-dryers to make land yacht races, etc. Ideally, a computer or computers should be available for students to explore the Jack and Jill animated activity briefings.

Students need to be able to construct in pairs facing each other or side-by-side. It is also an advantage to have a cupboard or shelves to store the sets lying flat with any unfinished models on top of them.



LEGO® Education 4C Approach

The activities follow LEGO Education's 4C approach; Connect, Construct, Contemplate, and Continue. This enables you to progress naturally through the activities.

Connect

Creating a connection between a past and new learning experience stimulates the growth of new knowledge. Each activity therefore provides a short text with insights into the purpose and function of the specific model. The text is supported by a short video of a real-life machine similar to the LEGO® model. Use the text and video as a starting point for a class discussion or you could draw on your own experiences to provide an engaging introduction to the activity.

Construct

The construction of models engages both hands and minds. Using the building instructions, students build models embodying the concepts related to the key learning areas. Tips are provided for testing and ensuring each model functions as intended.

Contemplate

Contemplating is the opportunity to deepen the understanding of previous knowledge and new experiences. Based on scientific method, the activities encourage the students to discuss and reflect on their investigations, and adapt their ideas to the task at hand.

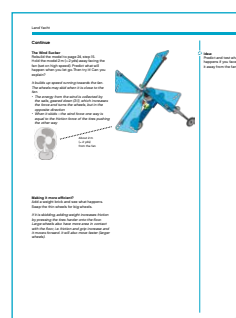
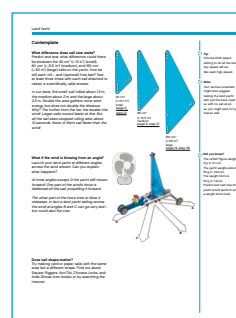
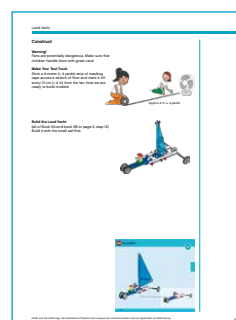
Each activity requires the students to predict an outcome, test, calculate and record their findings. We suggest encouraging the students to present their findings together with their explanations and rationales to each other.

We suggest stimulating the students' reflections on their investigations by having them consider patterns or trends in their findings, identify variables and describing advantages and disadvantages in model function and design.

This stage in the student's work process provides an opportunity for you to begin evaluating the learning outcome and progress of the individual student.

Continue

Learning is always more enjoyable and creative when it is adequately challenging. Maintaining this challenge and the pleasure of accomplishment naturally inspires the continuation of more advanced work. The open-ended continue activities challenge the students through a series of 'what if' questions to focus on particular features of the model that might be re-designed to give improved and optimized performance.





Curriculum Grid

Objective Number	NGSS Grade 6-8 ● = Fully covered ◐ = Partially covered	Activities													Problem-Solving Activities					
		Sweeper	Fishing Rod	Freewheeling	The Hammer	Trundle Wheel	Letter Balance	Click-Clock	Windmill	Land Yacht	Flywheeler	Power Car	Dragster	The Walker	Dogbot	Uphill Struggle	The Magic Lock	Stamping Letters	Beaten	The Lifter
Disciplinary Core Ideas: Physical Science																				
1	MS-PS2 Motion and Stability: Forces and Interactions	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
2	MS-PS3 Energy	◐	◐	●	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
Crosscutting Concepts																				
1	Patterns	◐	◐	●	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
2	Cause and effect	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
3	Scale, proportion, and quantity	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
4	Systems and system models	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
5	Energy and matter	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
6	Structure and Function	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
7	Stability and change	◐	◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
Science and Engineering Practices																				
1	Asking questions and Defining Problems	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
2	Developing and using models	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
3	Planning and carrying out investigations	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
4	Analyzing and interpreting data	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
5	Using mathematics, Informational and Computer Technology, and computational thinking	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
6	Constructing explanations and designing solutions	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
7	Engaging in argument from evidence	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
8	Obtaining, evaluating, and communicating information	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐

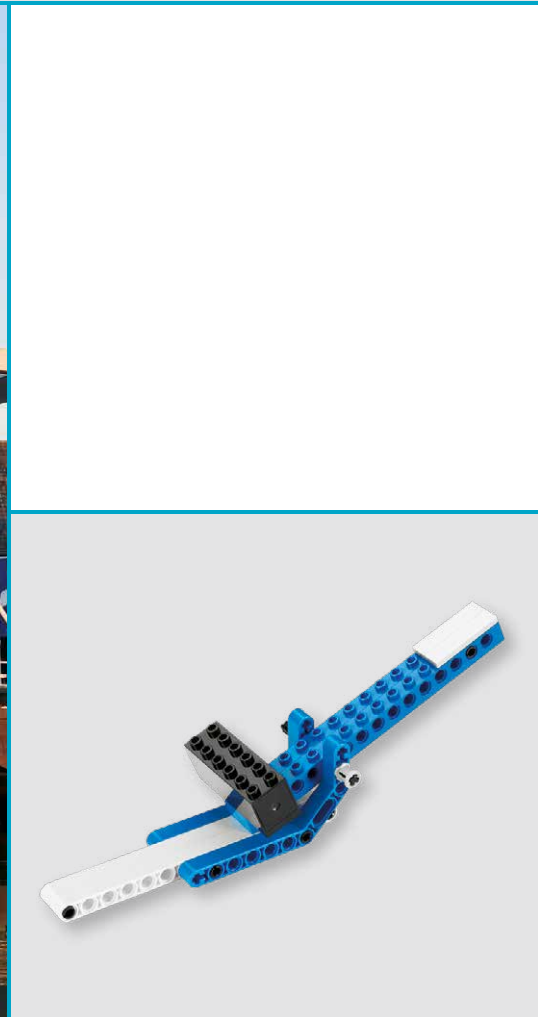
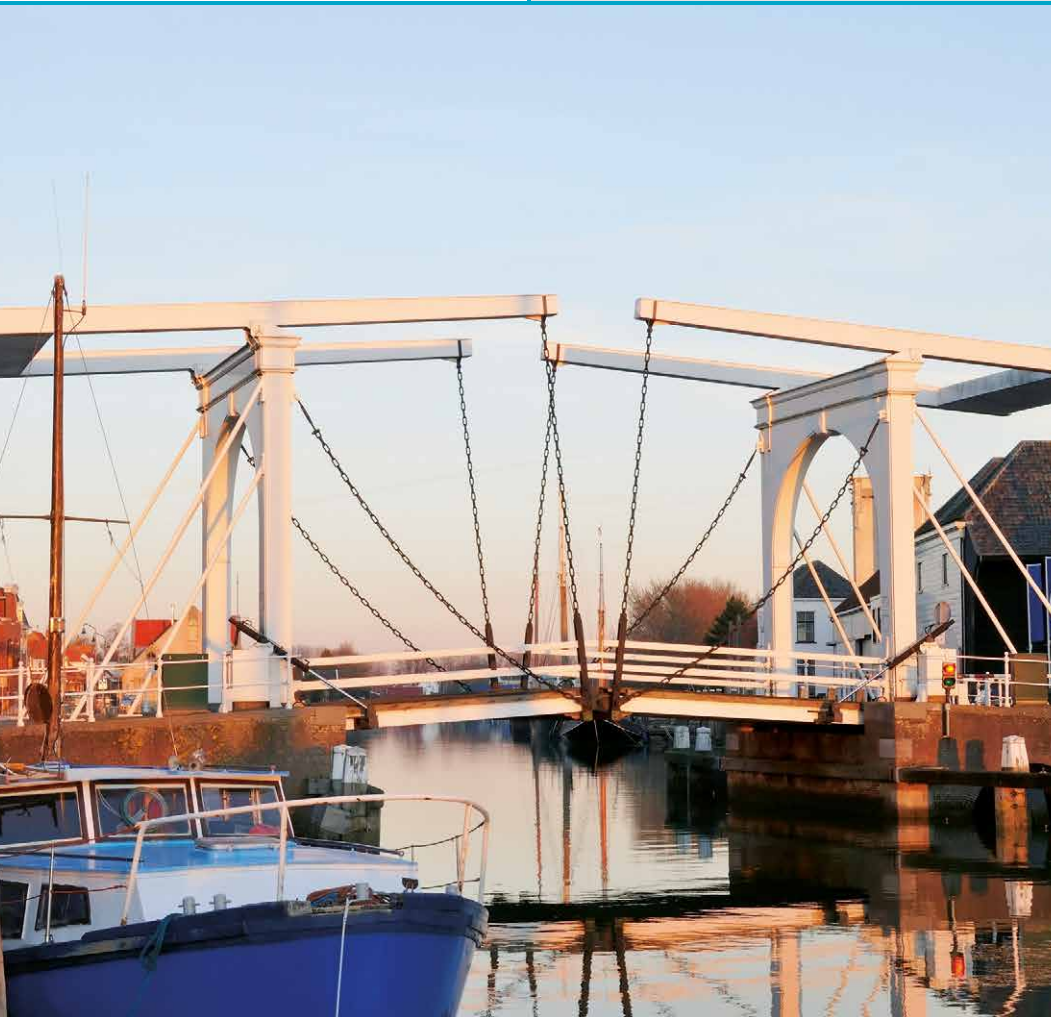
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Objective Number	Common Core English Language Arts Grade 6-8 ● = Fully covered ◐ = Partially covered	Activities														Problem-Solving Activities					
		Sweeper	Fishing Rod	Freewheeling	The Hammer	Trundle Wheel	Letter Balance	Click-Clock	Windmill	Land Yacht	Flywheeler	Power Car	Dragster	The Walker	Dogbot	Uphill Struggle	The Magic Lock	Stamping Letters	Beaten	The Lifter	The Bat
Speaking and Listening																					
SL 6.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
SL 6.2	Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
SL 6.3	Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not	◐		◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 6.4	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 6.5	Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 6.6	Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (See grade 6 Language standards 1 and 3 for specific expectations.)	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 7.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
SL 7.2	Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue under study	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 7.3	Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
SL 7.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 7.6	Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (See grade 7 Language standards 1 and 3 here for specific expectations.)	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
SL 8.2	Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 8.3	Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
SL 8.6	Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (See grade 8 Language standards 1 and 3 here for specific expectations.)	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐

Objective Number	Common Core English Language Arts Grade 6-8 ● = Fully covered ● = Partially covered	Activities														Problem-Solving Activities					
		Sweeper	Fishing Rod	Freewheeling	The Hammer	Trundle Wheel	Letter Balance	Click-Clock	Windmill	Land Yacht	Flywheeler	Power Car	Dragster	The Walker	Dogbot	Uphill Struggle	The Magic Lock	Stamping Letters	Beaten	The Lifter	The Bat
Reading Standards for Literacy in Science and Technical																					
RST 6-8.1	Cite specific textual evidence to support analysis of science and technical texts	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
RST 6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
RST 6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
RST 6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
RST 6-8.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
RST 6-8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Writing Standards for Literacy in History/Social Studies, Science, & Technical Subjects																					
WHST 6-8.1	Write arguments focused on discipline-specific content	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.5	With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.6	Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.8	Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.9	Draw evidence from informational texts to support analysis, reflection, and research	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
WHST 6-8.10	Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Lever

Student Worksheet



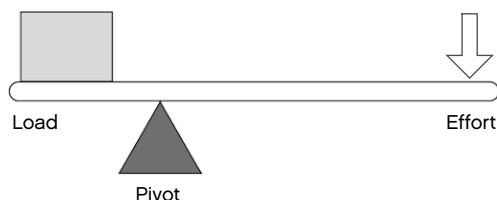
Simple Machines: Lever

The lever is probably the most commonly used simple machine. A lever is a rigid bar or solid object that is used to transfer force.

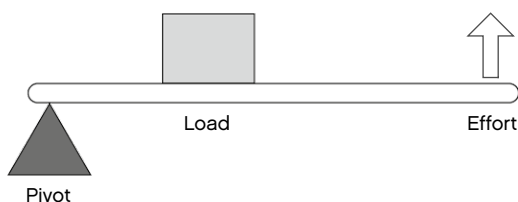
With a pivot, the lever can be used to change the force that is applied (effort), alter the direction, and change the distance of movement. An effort, a pivot, and a load are three features that are common in every lever.

Depending on the positions of these shared features, you can distinguish between first, second, or third class levers.

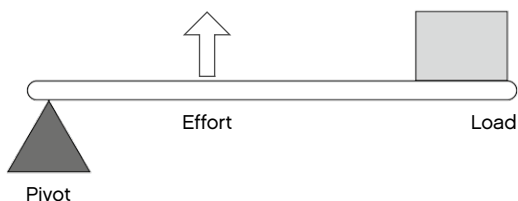
Did you know?
The term lever derives from the French word *levier* which means 'to raise'.



First class levers have the pivot positioned between the effort and the load. Common examples of first class levers include a seesaw, a crowbar, pliers, and scissors.



Second class levers have the pivot and the effort at opposite ends and the load positioned between the two. Common examples of second class levers include nutcrackers, wheelbarrows, and bottle openers.



Third class levers have the pivot and the load at opposite ends and the effort positioned between the two. Common examples of third class levers include tweezers and ice tongs.

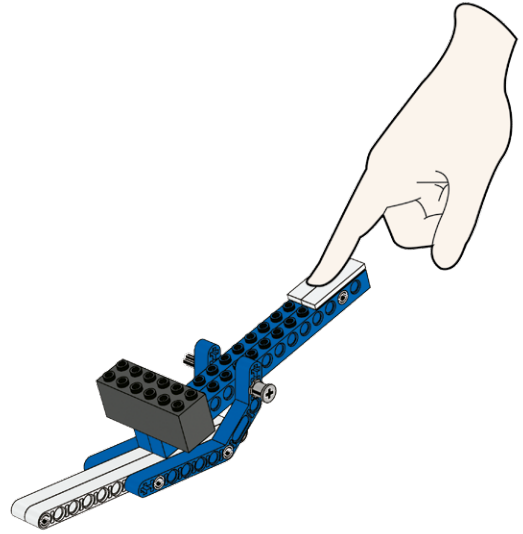
A1**Build A1 book I, pages 2 to 3**

Press down on the lever to lift the load.

Describe how hard or easy it was to lift the load.

Circle and label the pivot, load, and effort.

Which class of lever is this?

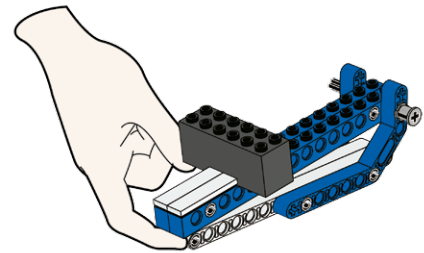
**A2****Build A2 book I, page 4 to 5**

Raise the lever.

Describe how hard or easy it was to lift the load.

Circle and label the pivot, load, and effort.

Which class of lever is this?

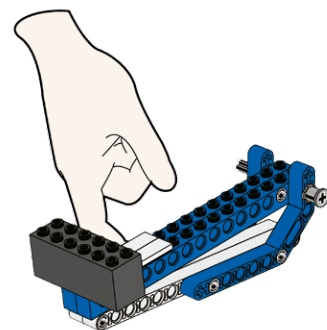
**A3****Build A3 book I, page 6 to 7**

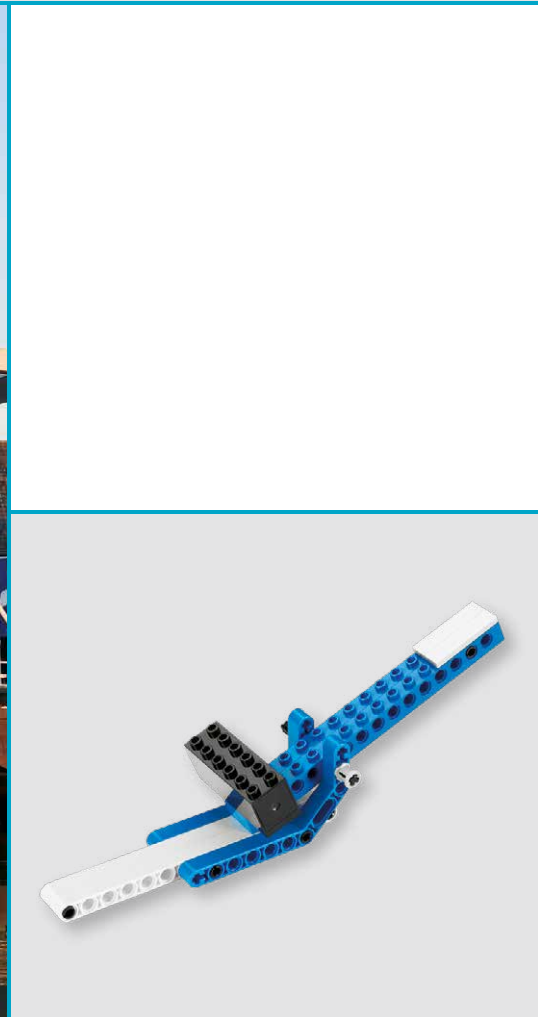
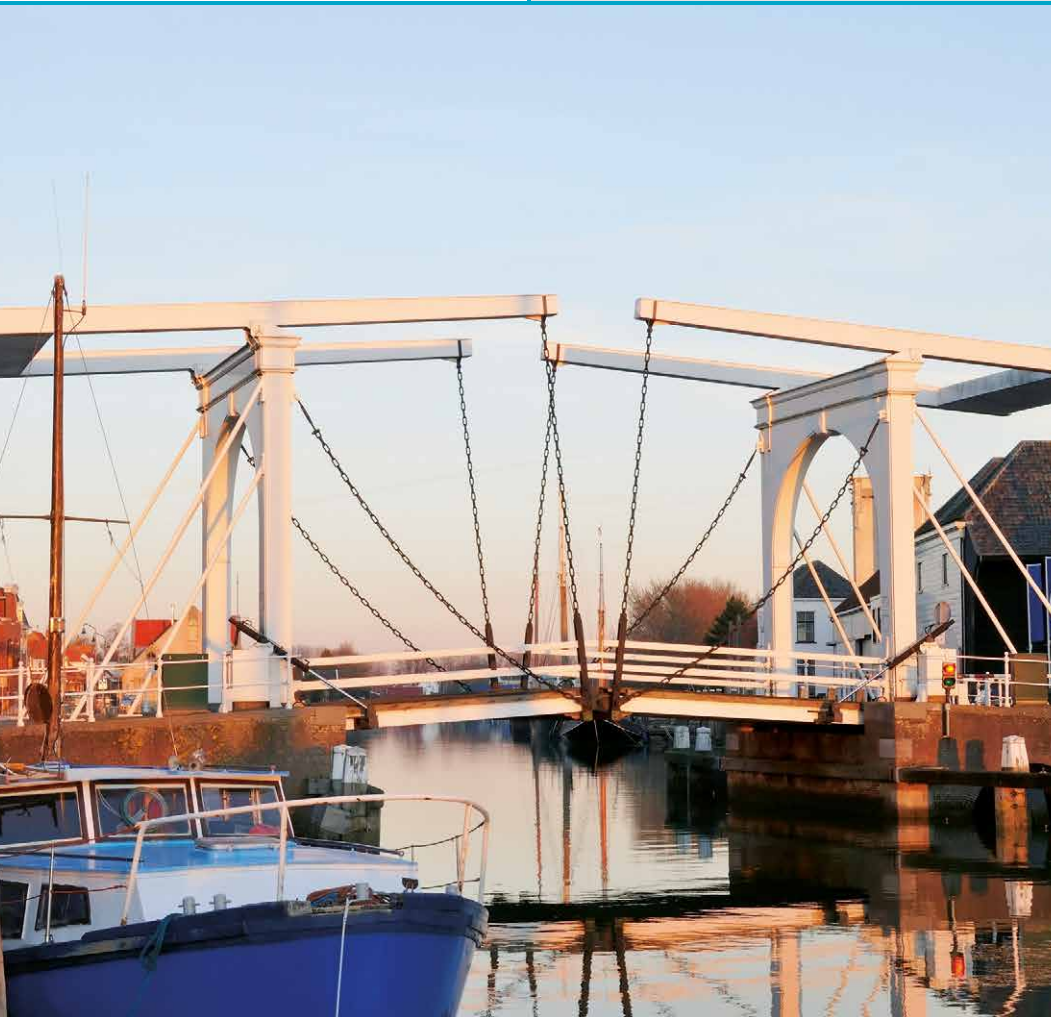
Raise the lever.

Describe how hard or easy it was to lift the load.

Circle and label the pivot, load, and effort.

Which class of lever is this?





Simple Machines: Lever

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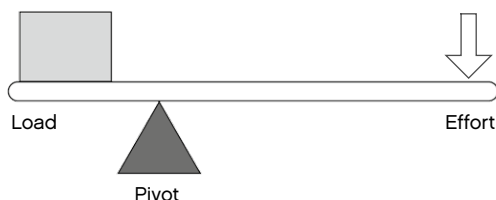
With a pivot, the lever can be used to change the force that is applied (effort), alter the direction, and change the distance of movement. Effort, a pivot, and a load are three features that are common in every lever.

Depending on the positions of these shared features, you can distinguish between first, second, or third class levers.

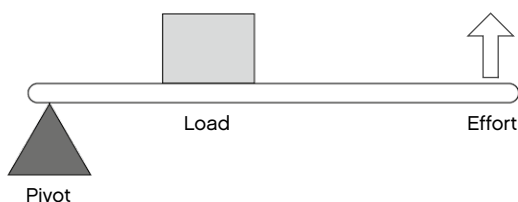


Did you know?

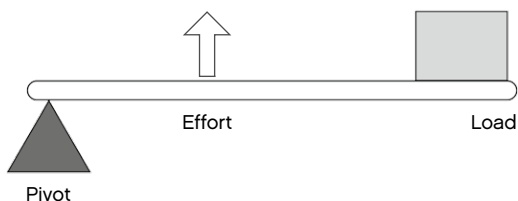
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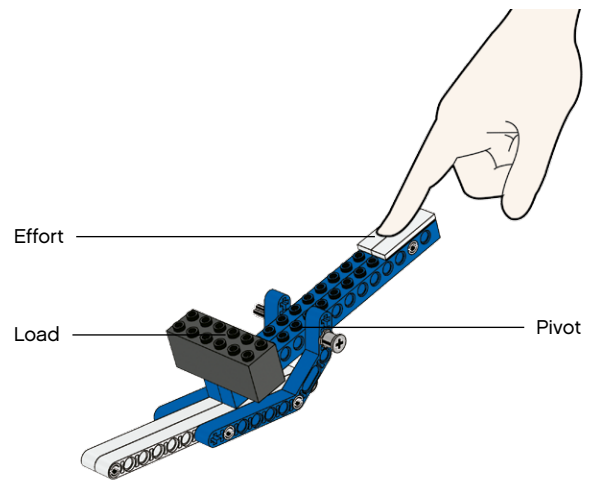
Second class levers have the pivot and the effort at opposite ends and the load positioned between the two. Common examples of second class levers include nutcrackers, wheelbarrows, and bottle openers.



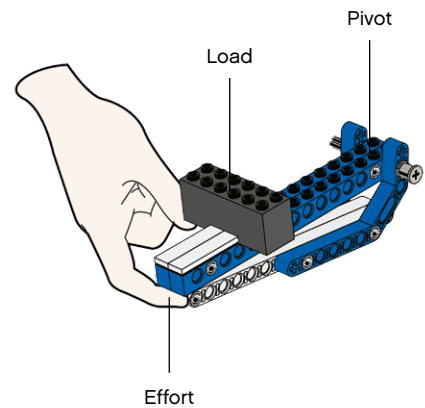
Third class levers have the pivot and the load at opposite ends and the effort positioned between the two. Common examples of third class levers include tweezers and ice tongs.

A1

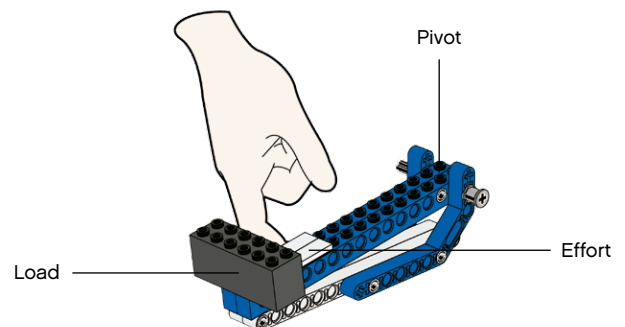
This model shows a first class lever. It has the effort and load at opposite ends with the pivot in between. This model uses the least effort to move the load.

**A2**

This model shows a second class lever. It has the effort and pivot at opposite ends and the load in between. The effort needed to move the load is about half the load force.

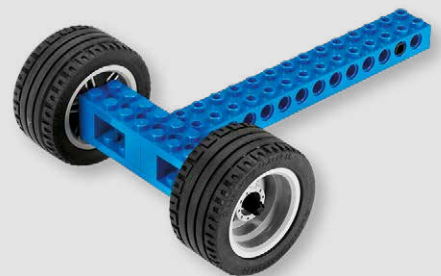
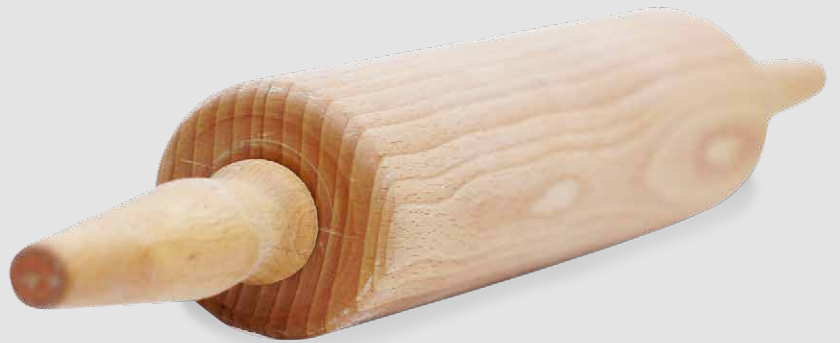
**A3**

This model shows a third class lever. It has the pivot and load at opposite ends and the effort in between. Even though the effort required is greater than lifting the load directly, the advantage of using a third class lever is that the load is moved a further distance than the length of the lift of the effort.



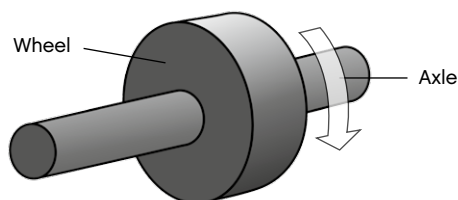
Wheel and Axle

Student Worksheet



Simple Machines: Wheel and Axle

Wheels and axles are usually circular objects, often a big wheel and a smaller axle, rigidly secured to one another.



The wheel and axle will always rotate at the same speed. Due to the bigger circumference of the wheel, the surface of the wheel will turn at a greater speed – and with a greater distance too.

Placing a load on a wheeled vehicle almost always reduces friction compared to dragging it over the ground. Wheels in science and engineering are not always used for transport. Wheels with grooves are called pulleys and wheels with teeth are called gears.

Common examples of wheels and axles are rolling pins, roller skates and pushcarts.

Did you know?

The first constructed wheel found so far was made by the Sumerians some 5,600 years ago.

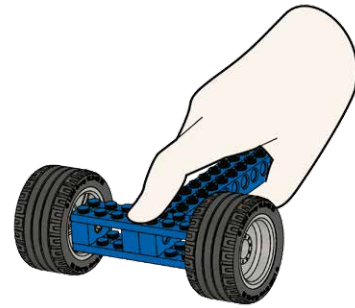
B1**Build B1 book I, page 8 to 9**

Push the model along the table in a straight line.

Describe what happens.

Now try driving it in a zigzag pattern with sharp turns.

Describe what happens.



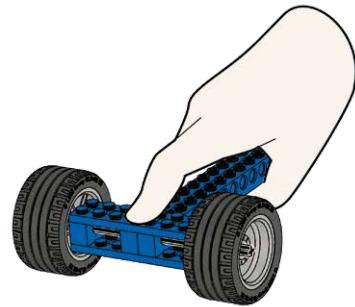
B2**Build B2 book I, page 10 to 11**

Push the model along the table in a straight line.

Describe what happens.

Now try driving it in a zigzag pattern with sharp turns.

Describe what happens and compare with the model above.



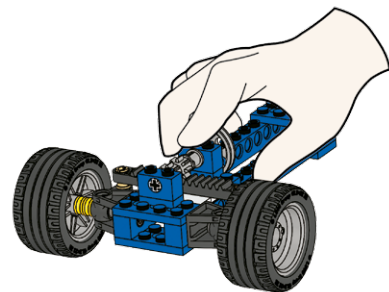
B3**Build B3 book I, page 12 to 15**

Push the model along the table in a straight line.

Describe what happens.

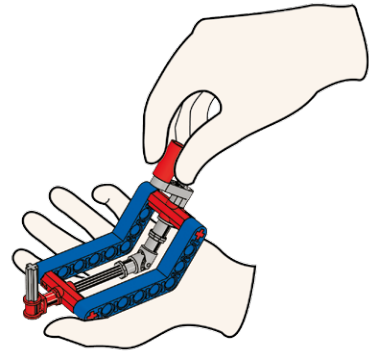
Now try driving it in a zigzag pattern with sharp turns.

Describe what happens and compare with the models above.



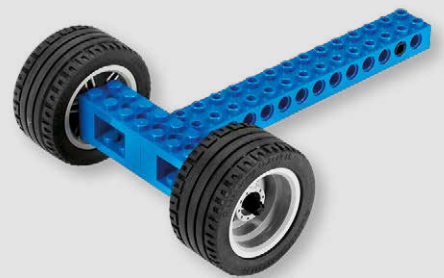
B4**Build B4 book I, page 16 to 17**

Describe what happens and the movement of the universal joint when you turn the handle.



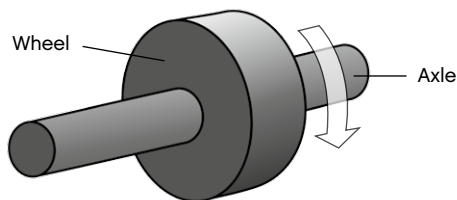
Wheel and Axle

Teacher's Notes



Simple Machines: Wheel and Axle

Wheels and axles are usually circular objects, often a big wheel and a smaller axle, rigidly secured to one another.



The wheel and axle will always rotate at the same speed. Due to the bigger circumference of the wheel, the surface of the wheel will turn at a greater speed – and with a greater distance too.

Placing a load on a wheeled vehicle almost always reduces friction compared to dragging it over the ground. Wheels in science and engineering are not always used for transport. Wheels with grooves are called pulleys and wheels with teeth are called gears.

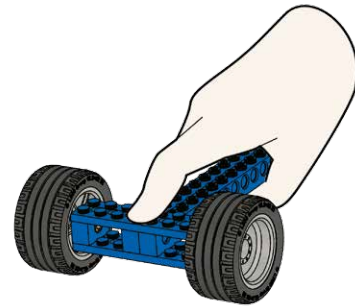
Common examples of wheels and axles are rolling pins, roller skates and pushcarts.

Did you know?

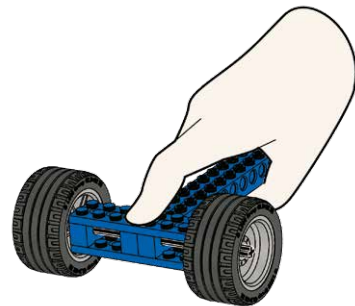
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B1

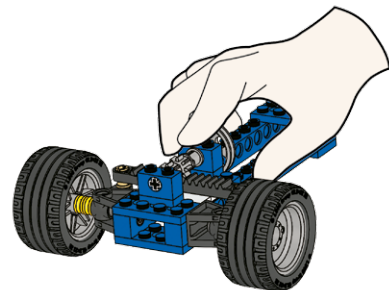
This model shows a cart with split axles. It is very easy to steer both when driving in a straight line or when following zigzag patterns involving sharp turns. The split axles allow the wheels to turn at different speeds.

**B2**

This model shows a cart with fixed axles. It is very easy to steer when driving in a straight line. However, it is hard to steer when following zigzag patterns involving sharp turns as the wheels cannot turn at different speeds. One wheel will always skid when turning corners.

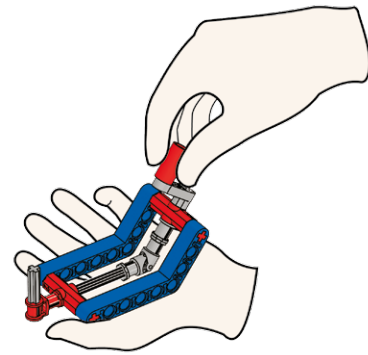
**B3**

This model shows a cart with a steering system. It is very easy to steer both when driving in a straight line or when following zigzag patterns involving sharp turns. The split axles allow the wheels to turn at different speeds and the steering wheel provides good control.



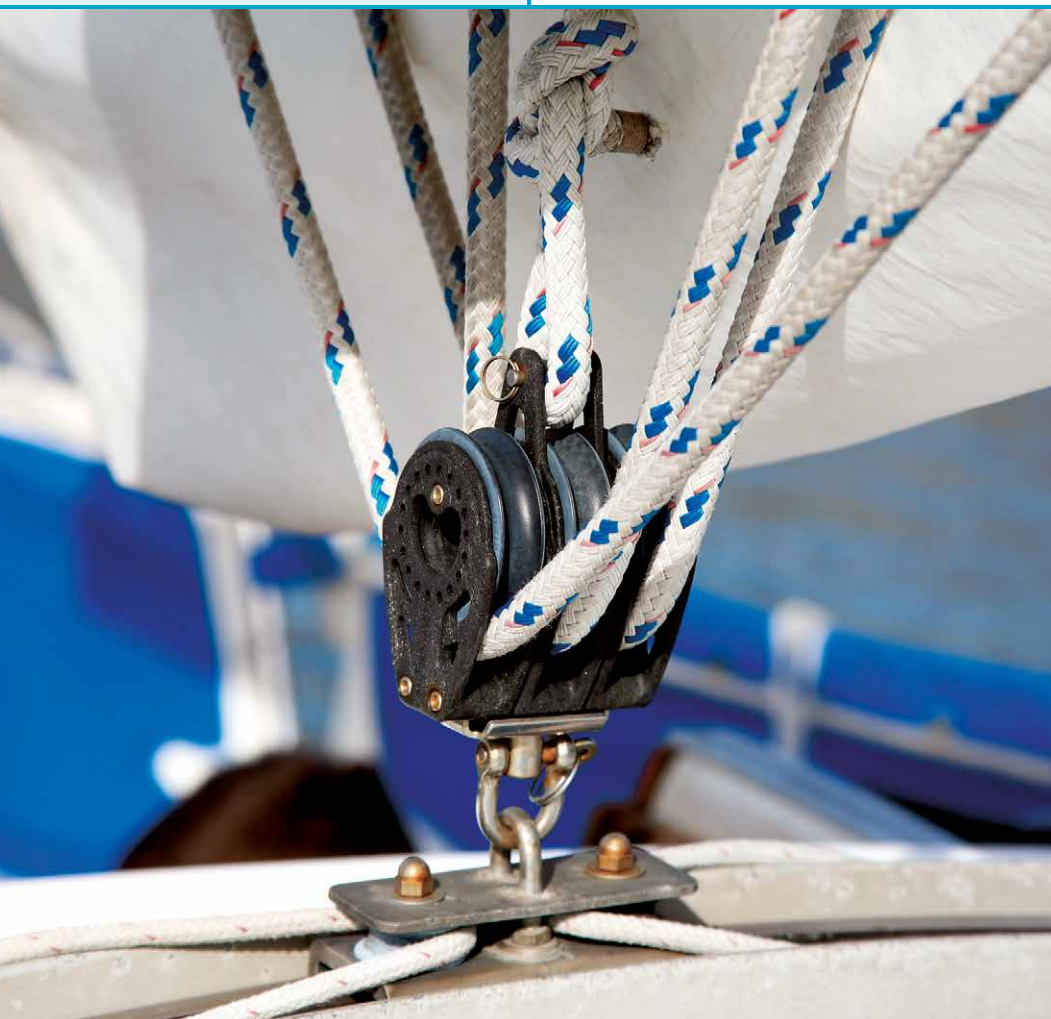
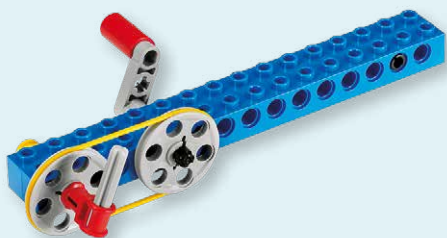
B4

This model shows a universal joint. When the handle is turned the rotary motion is transmitted through the universal joint at an angle to the output. The speed ratio between input and output is 1:1.



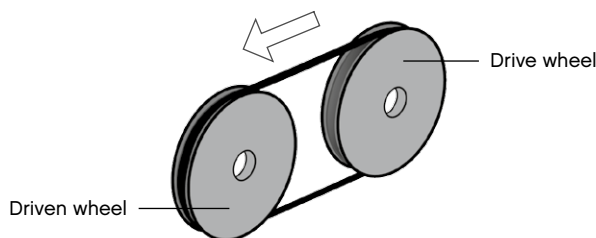
Pulley

Student Worksheet



Simple Machines: Pulley

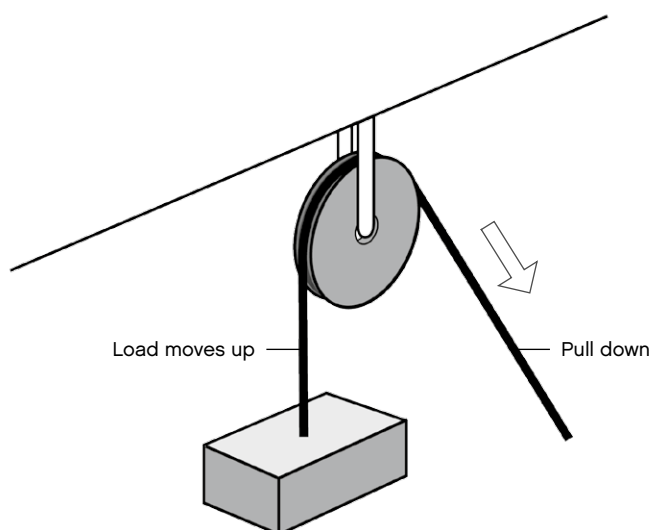
Pulleys are wheels that are moved by ropes, chains or belts around their rims.



In a belt driven pulley a continuous belt joins two pulley wheels. The wheel to which an external force is applied (effort) is called the drive wheel, and the other the driven wheel. The drive pulley wheel provides the input force and the driven pulley wheel delivers the output force. When the drive wheel turns the belt moves and causes the driven wheel to turn in the same direction. If the drive wheel is smaller than the driven wheel, the driven wheel will turn more slowly than the drive wheel.

Belt driven pulleys rely on belt friction to transmit motion. If the belt is too tight the belt will create wasteful friction forces on the pulley axle and bearing. If too loose the belt will slip and the effort is not used efficiently. Slip is an overload protection safety feature of belt-operated machinery.

For heavy lifting jobs; multiple pulley wheels can be combined into a lifting system that makes lifting heavy objects easier.



Using a single pulley to lift a load doesn't make it easier, but it changes the direction of motion without any gains in speed or required effort. It only allows you to lift a load up by the pulling of the rope. Pulleys can be either movable or fixed. The difference between fixed and movable pulleys are that fixed pulleys do not move up or down when the load is being moved. A fixed pulley is often fixed to an overhead beam or rafter and will only be able to rotate around its own axle. The use of multiple pulley wheels on one axle, in a lifting or dragging system, is called a Block and Tackle.

Common examples of pulleys are found in window blinds, curtains and flagpoles.

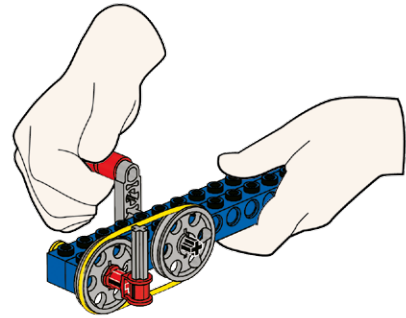
Did you know?

Pulleys started the age of mass production in England, when they were produced at the beginning of the 19th century to supply the British Royal Navy with pulley blocks for their war ships during the Napoleonic Wars.

C1**Build C1 book I, page 18**

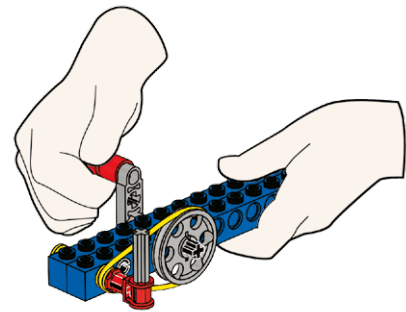
Turn the handle and describe the speeds of the drive and the driven pulley wheels.

Then gently increase your grip on the output pointer and describe what happens.

**C2****Build C2 book I, page 19**

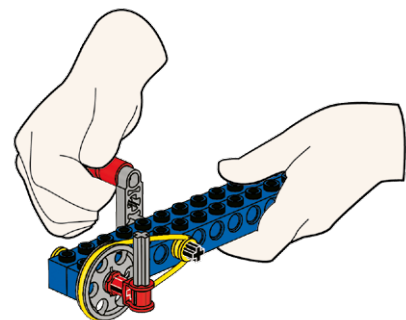
Turn the handle and describe the speeds of the drive and the driven pulley wheels.

Then gently increase your grip on the output pointer and describe what happens.

**C3****Build C3 book I, page 20**

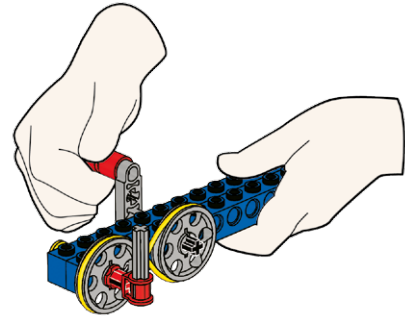
Turn the handle and describe the speeds of the drive and the driven pulley wheels.

Then gently increase your grip on the output pointer and describe what happens.

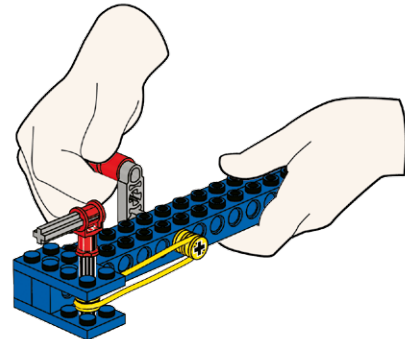


C4**Build C4 book I, page 21**

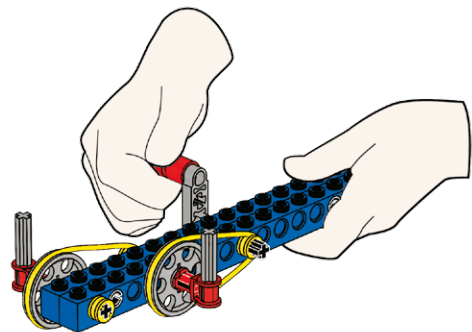
Turn the handle and describe the speeds of the drive and the driven pulley wheels. Then gently increase your grip on the output pointer and describe what happens.

**C5****Build C5 book I, page 22 to 23**

Turn the handle and describe the speeds of the drive and driven pulley wheels. Label the drive and driven pulley wheels. Use a circle to show exactly where each one is.

**C6****Build C6 book I, page 24 to 25**

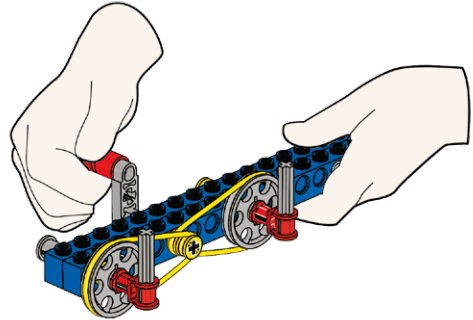
Turn the handle and describe the speeds of the drive and driven pulley wheels. Label the drive and driven pulley wheels. Use a circle to show exactly where each one is.



C7**Build C7 book I, page 26 to 27**

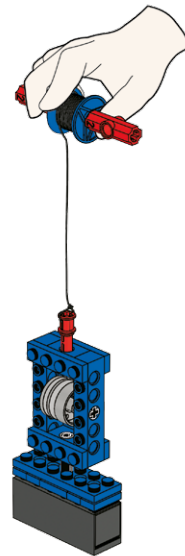
Turn the handle and describe the speeds of the drive and driven pulley wheels.

Label the drive and driven pulley wheels. Use a circle to show exactly where each one is.



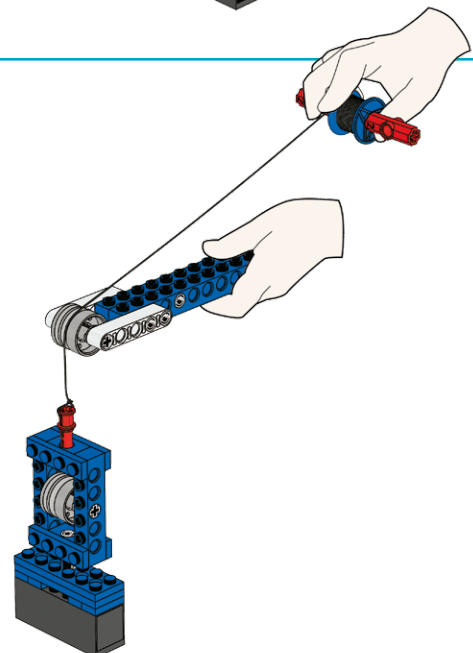
C8**Build C8 book I, page 28 to 31**

Lift the string to lift the load. Describe what happens.



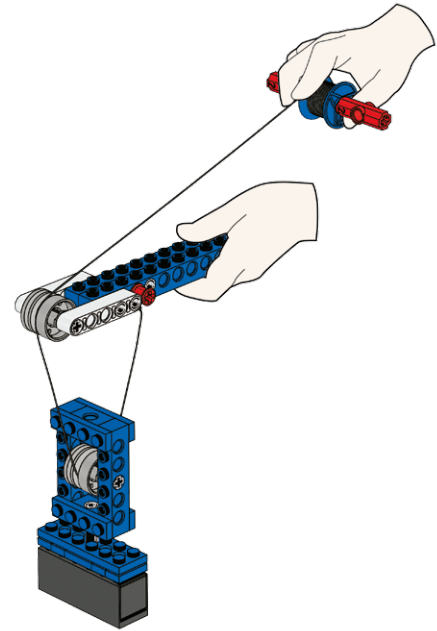
C9**Build C9 book I, page 32 to 35**

Pull the string to lift the load. Describe what happens.



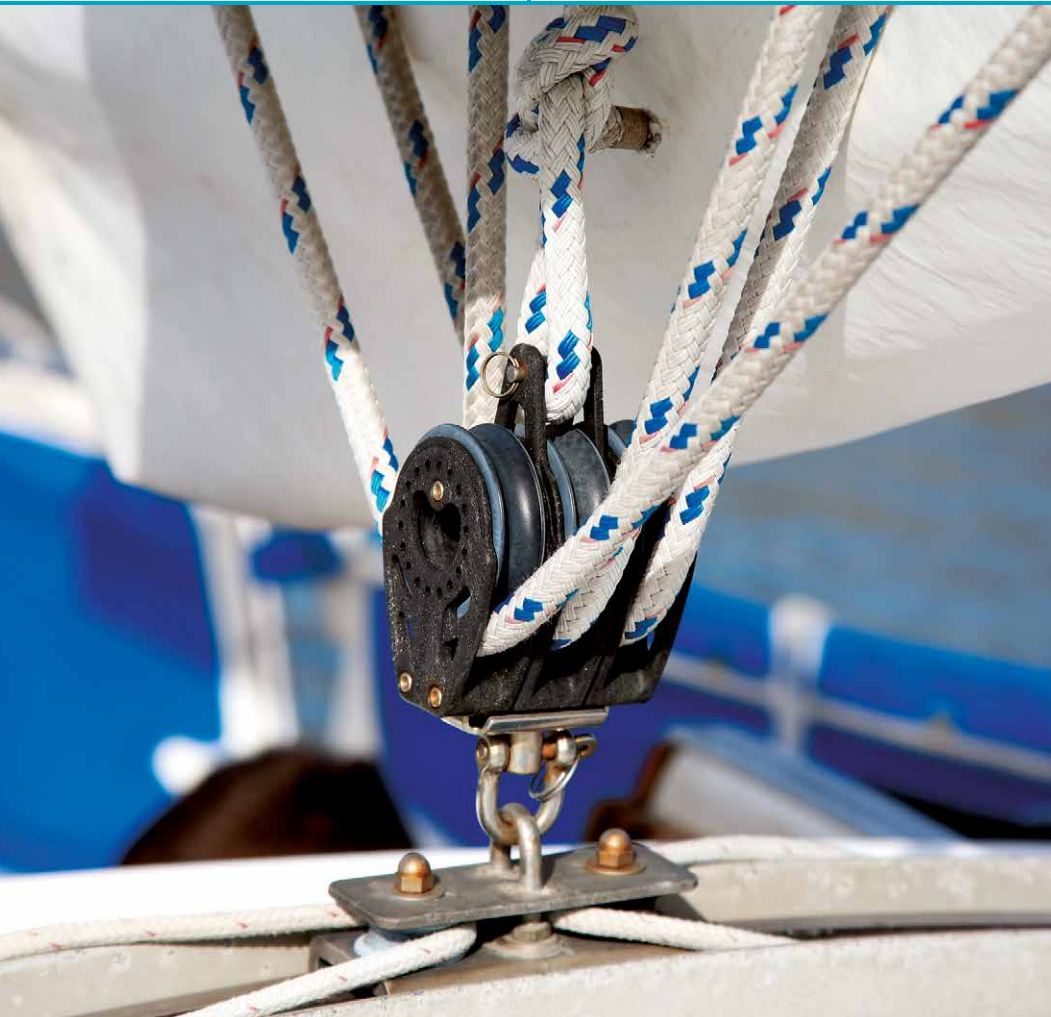
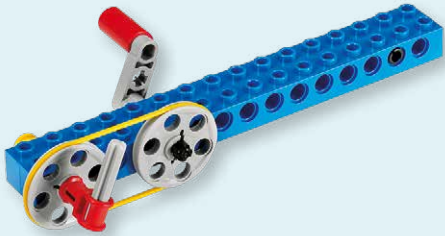
C10**Build C10 book 1, page 36**

Pull the string to lift the load. Describe what happens.



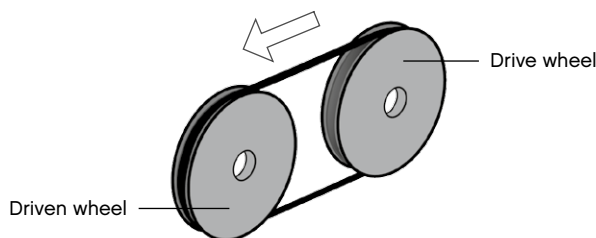
Pulley

Teacher's Notes



Simple Machines: Pulley

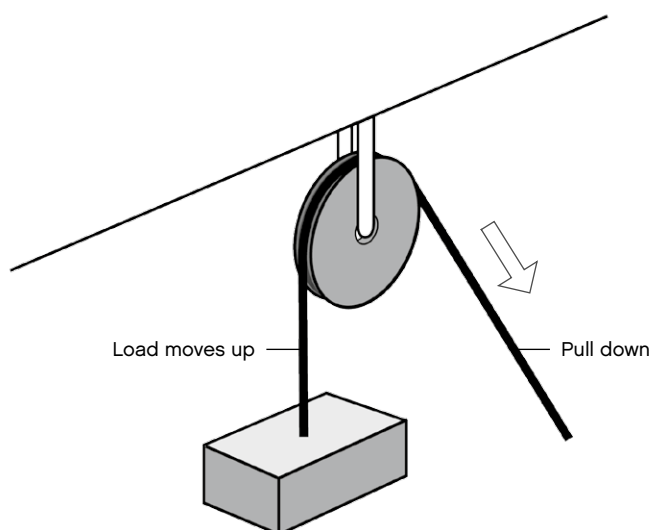
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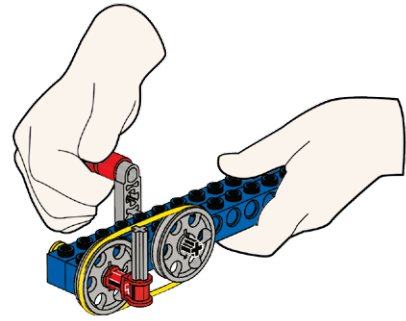
Common examples of pulleys are found in window blinds, curtains and flagpoles.

Did you know?

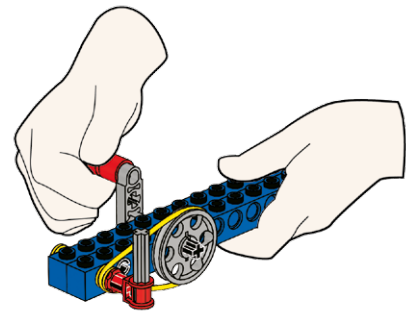
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C1

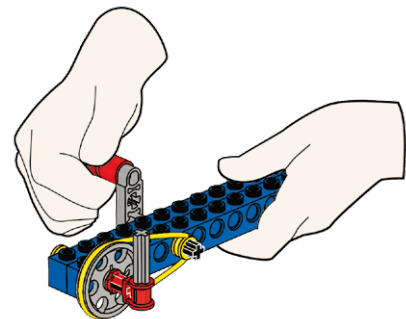
This model shows a belt driven pulley where the speed and direction of the drive and driven pulley wheels are the same. A light grip on the output pointer will stop the driven pulley wheel from turning, as this causes the belt to slip.

**C2**

This model shows a belt driven pulley where there is an increase in speed. The driven pulley wheel turns faster than the drive pulley wheel, but the output force is reduced and the belt can slip.

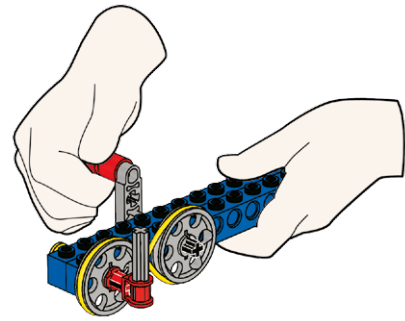
**C3**

This model shows a belt driven pulley where there is a decrease in speed. The driven pulley wheel turns slower than the drive pulley wheel. This increases the output force, but the belt slips with increasing load.

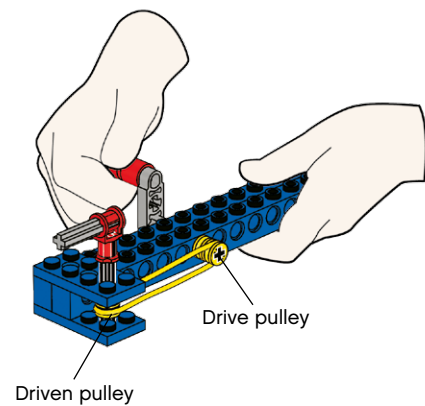


C4

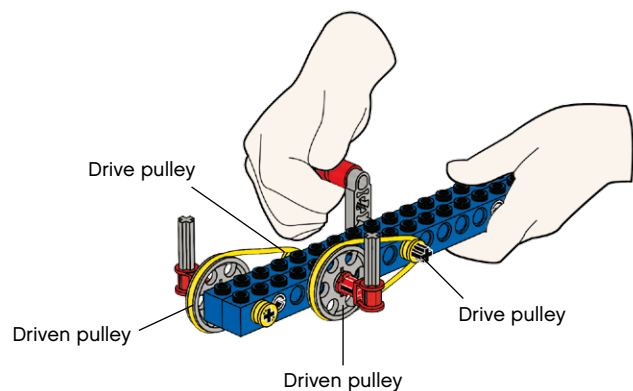
This model shows a belt driven pulley where the speed of the drive and driven pulley wheels are the same, but they turn in opposite directions because the belt crosses over.

**C5**

This model shows a belt driven pulley where the speed of the drive and driven pulley wheels are the same, but there is a change in the angle of motion caused by the twist in the belt.

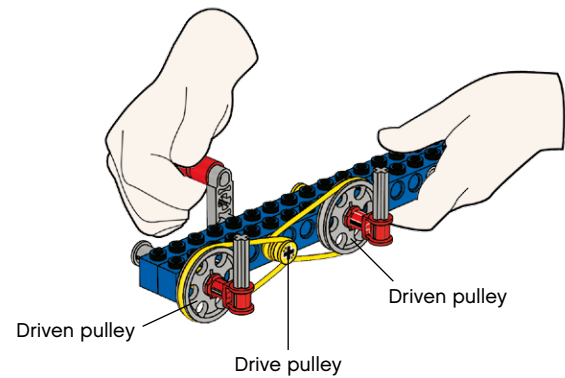
**C6**

This model shows a belt driven pulley using a compound pulley system. This reduces speed significantly, but at the same time significantly increase the output force. The smaller drive pulley wheel causes the larger driven pulley wheel to move slower. The small drive pulley wheel on the same axle as the larger driven pulley wheel becomes the drive pulley wheel of the second, large driven pulley wheel.

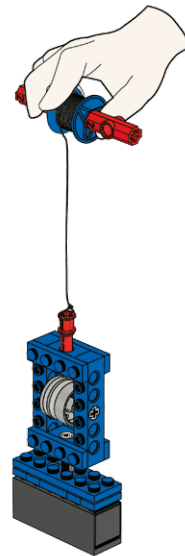


C7

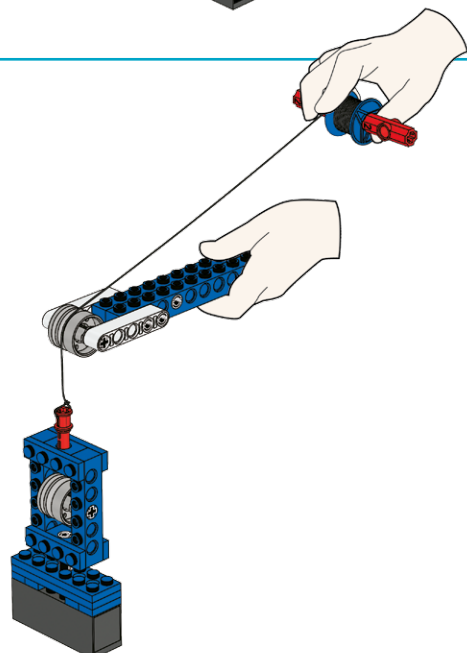
This model shows a belt driven pulley where one drive pulley drives two driven pulley wheels, creating double output. The difference in size of the drive and driven pulley wheels causes a reduction in speed, but an increased output force.

**C8**

This model generates no increase or reduction in the required effort, speed or distance. The full load of the LEGO® weight element is simply lifted or lowered.

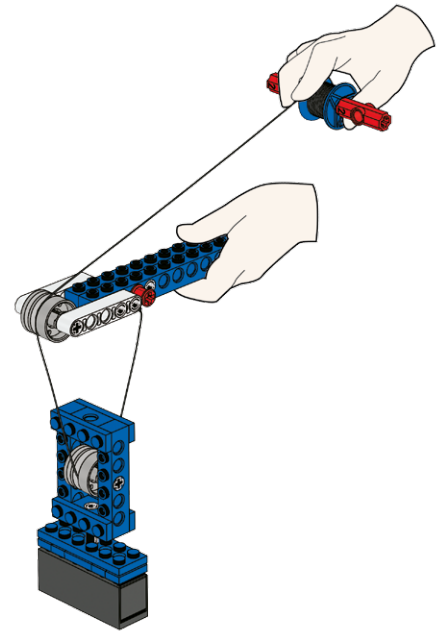
**C9**

This model shows a single fixed pulley. It generates no increase or reduction of required effort or speed, but merely changes the direction of motion.



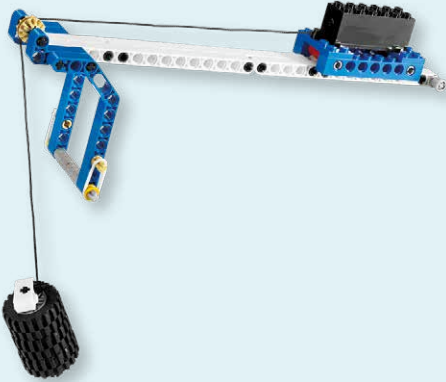
C10

This model shows a fixed and a movable pulley. It halves the effort needed to lift the load, but also reduces the speed at which the load is lifted. You must pull twice the length of string to lift the load.



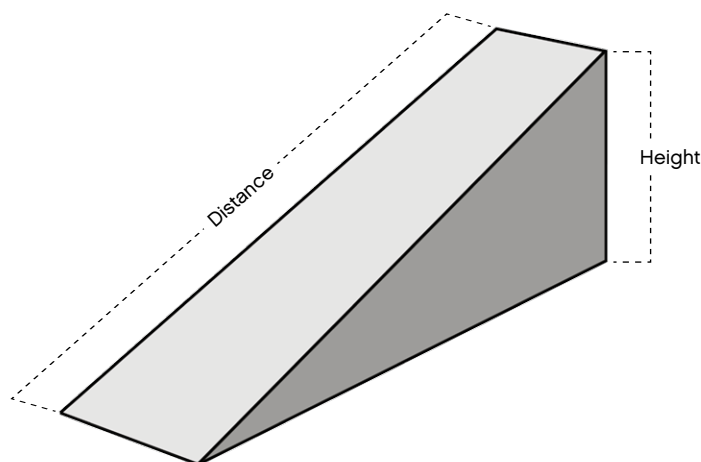
Inclined Plane

Student Worksheet



Simple Machines: Inclined Plane

An inclined plane is a slanted surface used to raise objects. One example is a ramp.



Using an inclined plane to raise an object to a given height, the object must be moved a longer distance, but with less effort needed than if the object was to be raised straight up. It is a trade-off either to use a lot of effort to raise a given load a short distance straight upwards or to apply much less force to raise it gradually over the longer distance of an inclined plane. That means the same amount of work is done.

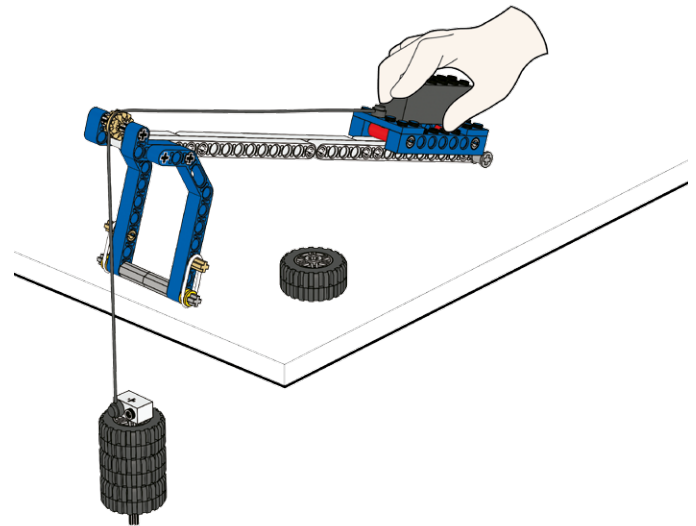
Common examples of inclined planes are ramps, ladders, and stairs.

Did you know?

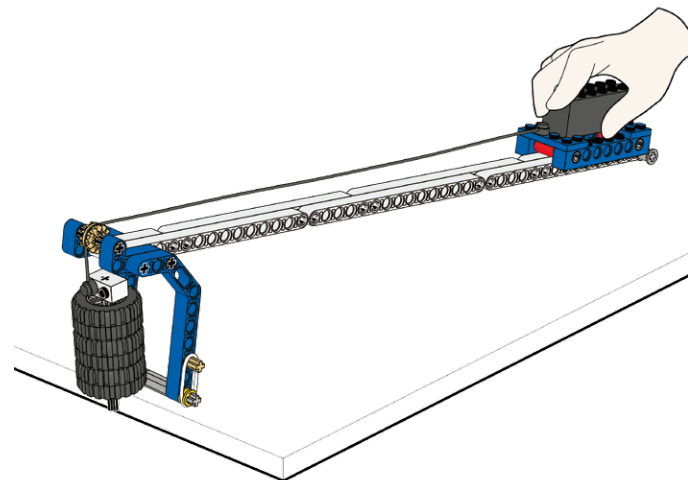
The advantage of using an inclined plane has been known and used for thousands of years. The ancient Egyptians used inclined planes made of earth to ease the transport of their giant stone blocks to the top of the pyramids.

D1**Build D1 book II, page 2 to 12**

Release the load. Describe what happens.

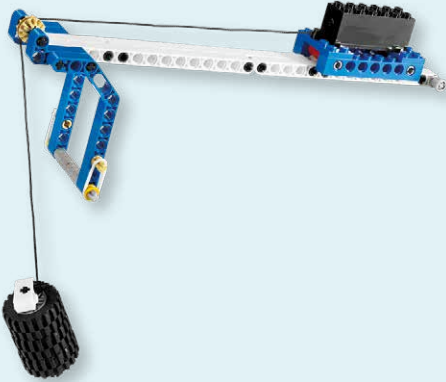
**D2****Build D2 book II, page 13 to 15**

Release the load. Describe what happens.



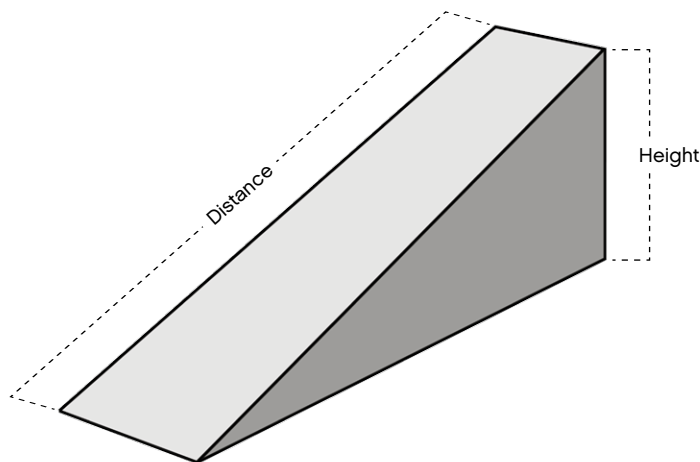
Inclined Plane

Teacher's Notes



Simple Machines: Inclined Plane

An inclined plane is a slanted surface used to raise objects, e.g. a ramp.



Using an inclined plane to raise an object to a given height, the object must be moved a longer distance, but with less effort needed than if the object was to be raised straight up. It is a trade-off either to use a lot of effort to raise a given load a short distance straight upwards or to apply much less force to raise it gradually over the longer distance of an inclined plane. That means the same amount of work is done.

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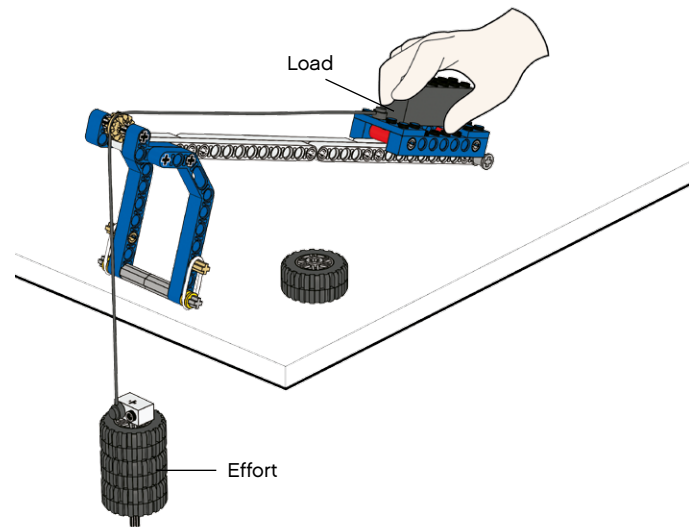


Did you know?

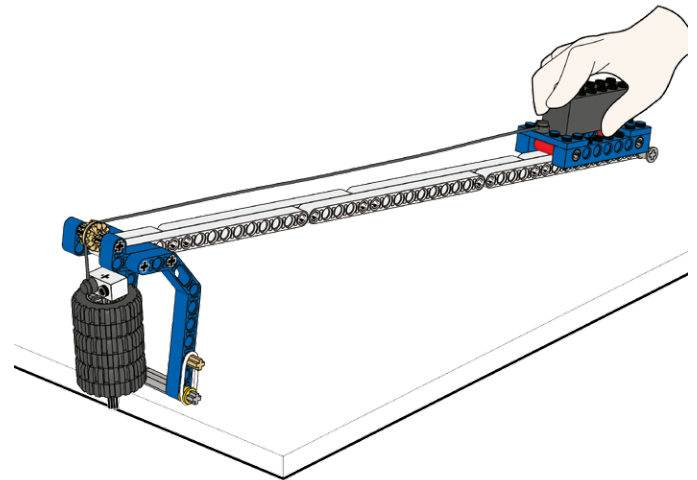
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D1

This model shows a short inclined plane. Nothing happens when the load is released. The effort is not enough to raise the load to the top of the inclined plane. If another wheel is added, the effort is able to raise the load.

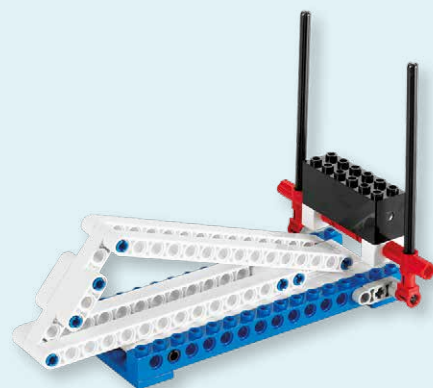
**D2**

This model shows a long inclined plane. Because of the added distance to this inclined plane, that reduced angle of the ramp, the effort is able to raise the load to the top of the inclined plane.



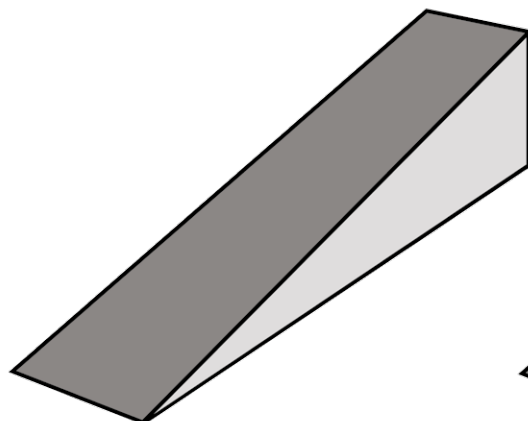
Wedge

Student Worksheet

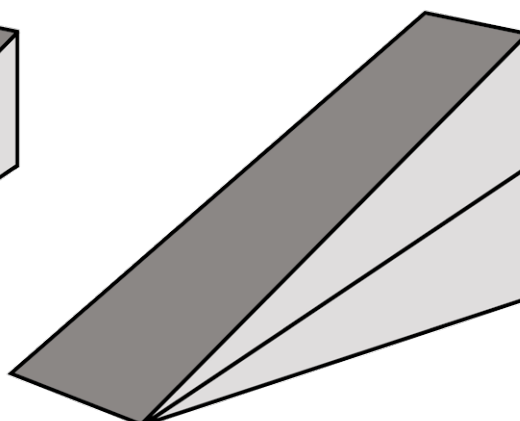


Simple Machines: Wedge

A wedge is a modification of the inclined plane. Unlike an inclined plane a wedge can move.



Single wedge



Double wedge

A wedge can have a single or two sloping surfaces. The effort you need depends on the relationship between the length and width of the wedge and consequently the sloping surface.

Common examples of wedges include axes, knives and doorstops.

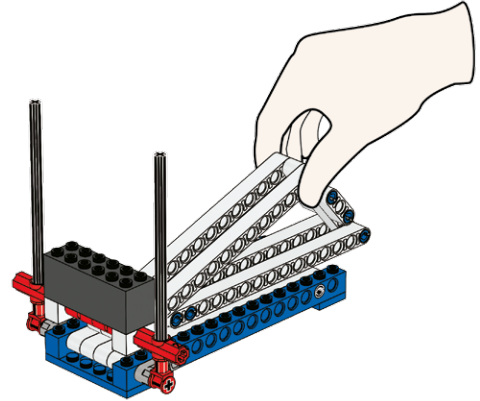
Did you know?

Wedges are used to split granite!

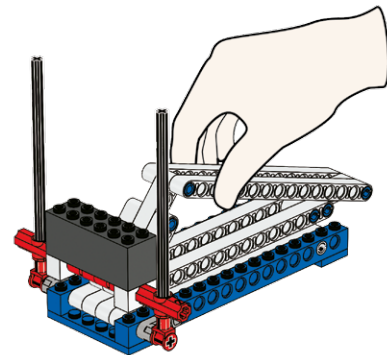
A simple device called a wedge and feather can split huge granite blocks.

E1**Build E1 book II, page 16 to 25**

Push the wedge under the load. Describe what happens.

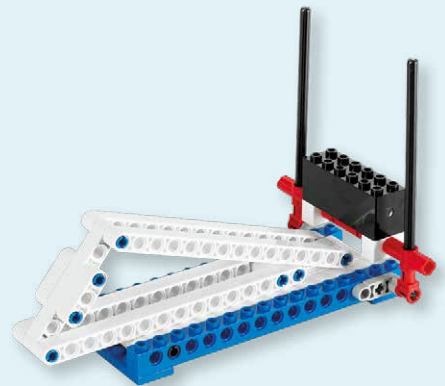
**E2**

Turn the wedge around and then push the wedge under the load again. Describe what happens and compare with the model above.



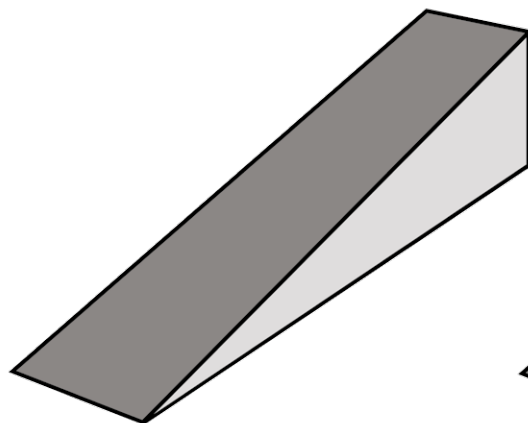
Wedge

Teacher's Notes

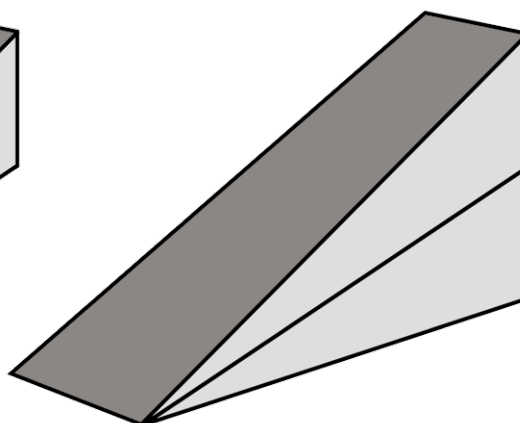


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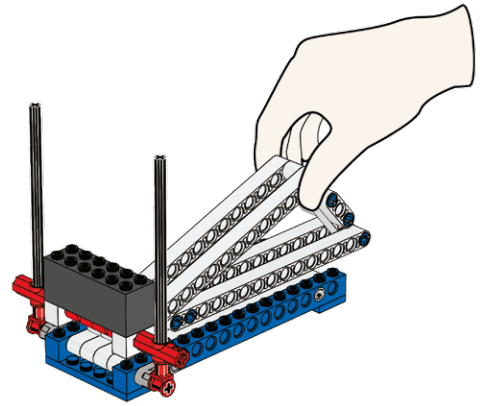
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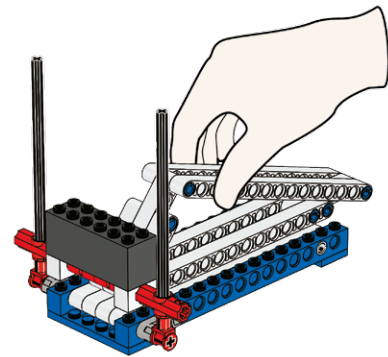
A simple device called a wedge and feather can split huge granite blocks.

E1

This model shows a single wedge with a long sloping surface. The wedge needs a small effort to lift the load as the wedge has a small angle.

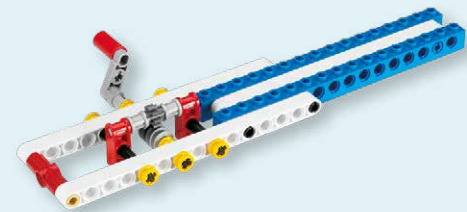
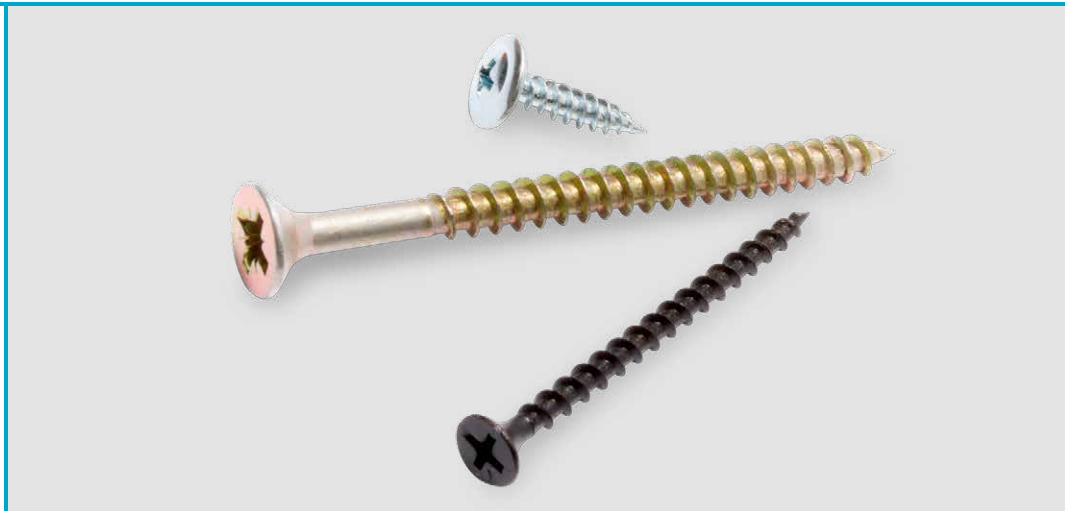
**E2**

This model shows a single wedge with a short sloping surface. The steep angle of the sloping surface needs a greater effort to lift the load compared to the previous wedge. But it also travels a shorter distance.



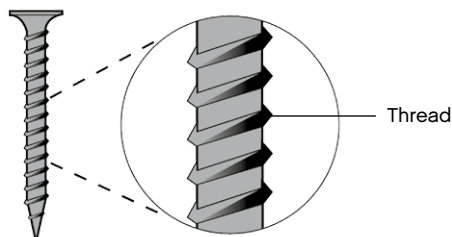
Screw

Student Worksheet



Simple Machines: Screw

A screw is a modification of an inclined plane. The threads of a screw are like an inclined plane wrapped around a cylinder. The width of the treads are like the angle of an inclined plane.



The finer the pitch of the screw, the more turns are required, but the less effort is needed to drive the screw in. The load is the friction and other forces exerted by the wood on the screw.

When a screw is screwed into a piece of wood, it is like rotating the long inclined plane through the load. The effort of a turning screwdriver is converted into a vertical effort that screws the screw into an object. How far the screw is able to move in one complete revolution is determined by the pitch of the screw.

The pitch is the number of threads per cm of screw. If a screw has 8 threads in a cm the screw has a pitch of $\frac{1}{8}$. A screw with a pitch of $\frac{1}{8}$ will in one complete revolution move a distance of $\frac{1}{8}$ of a cm into an object.

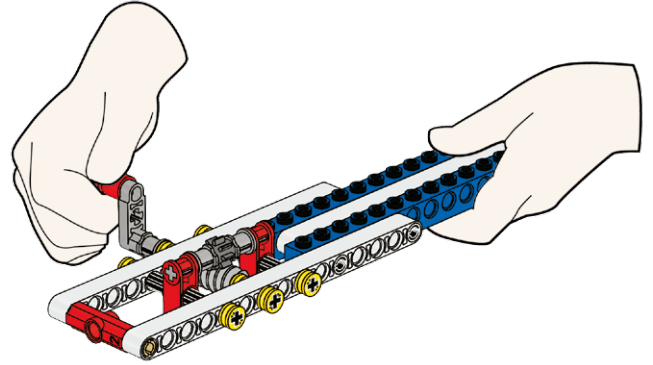
Common examples of screws are cork screws and drills.

Did you know?

Archimedes, the Greek scientist, mathematician and inventor, used a screw as the basis for his screw-pump design to move water for irrigation in the 3rd century BC.

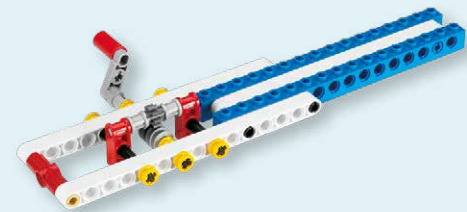
F1**Build F1 book II, page 26 to 32**

Turn the handle and describe what happens to the speed and the direction.



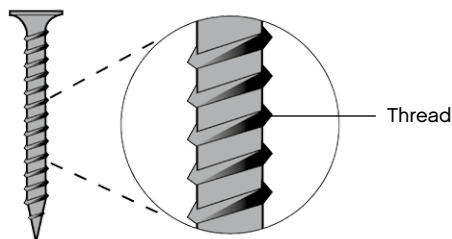
Screw

Teacher's Notes



Simple Machines: Screw

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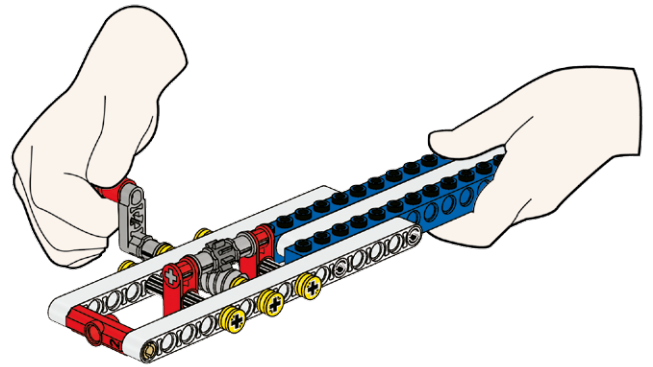


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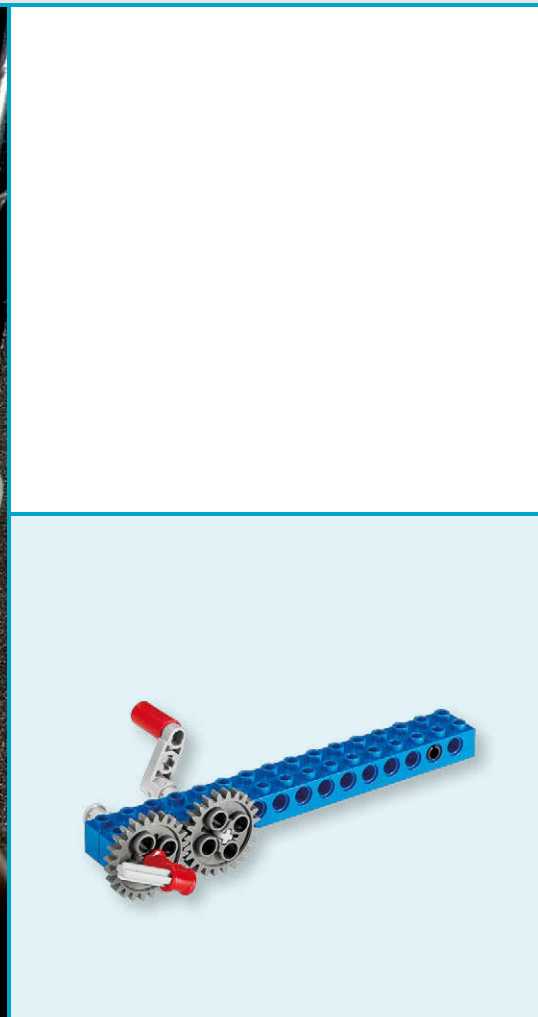
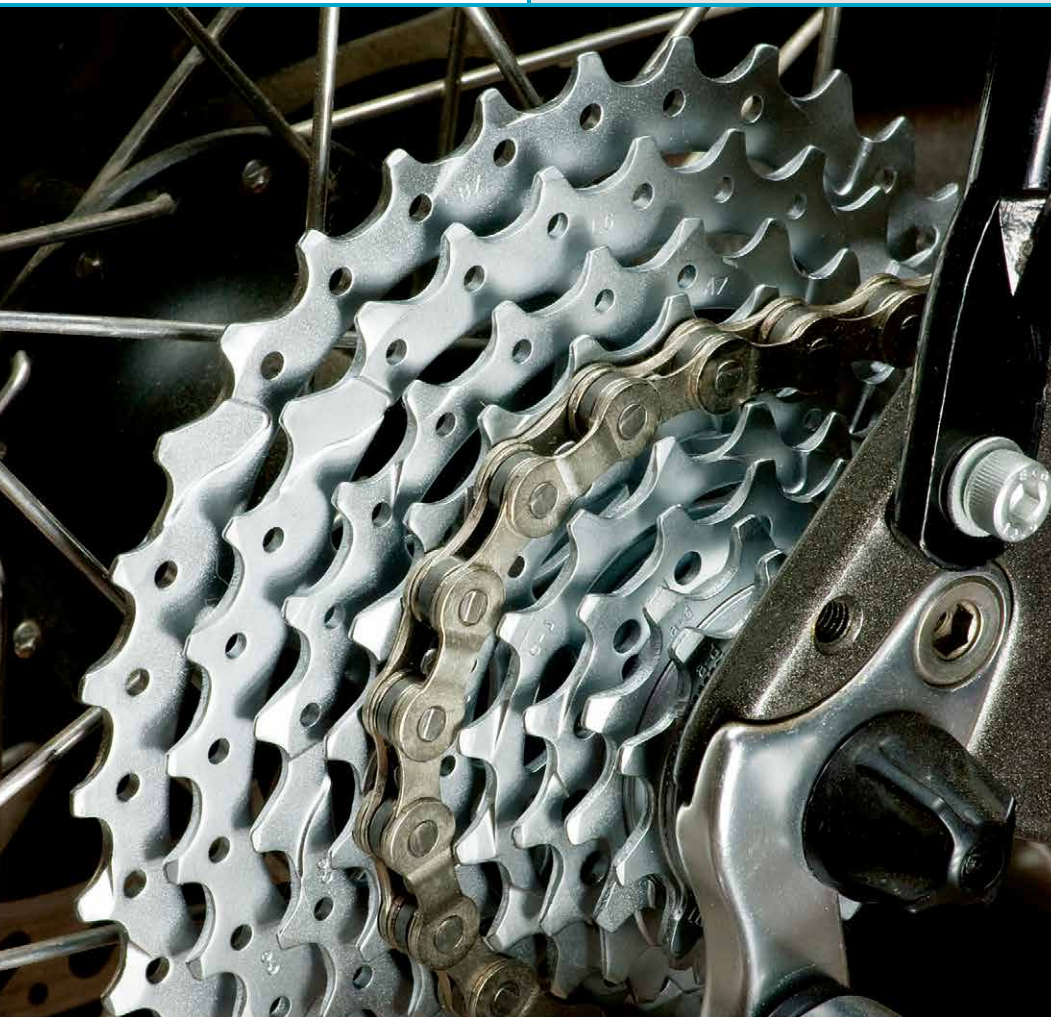
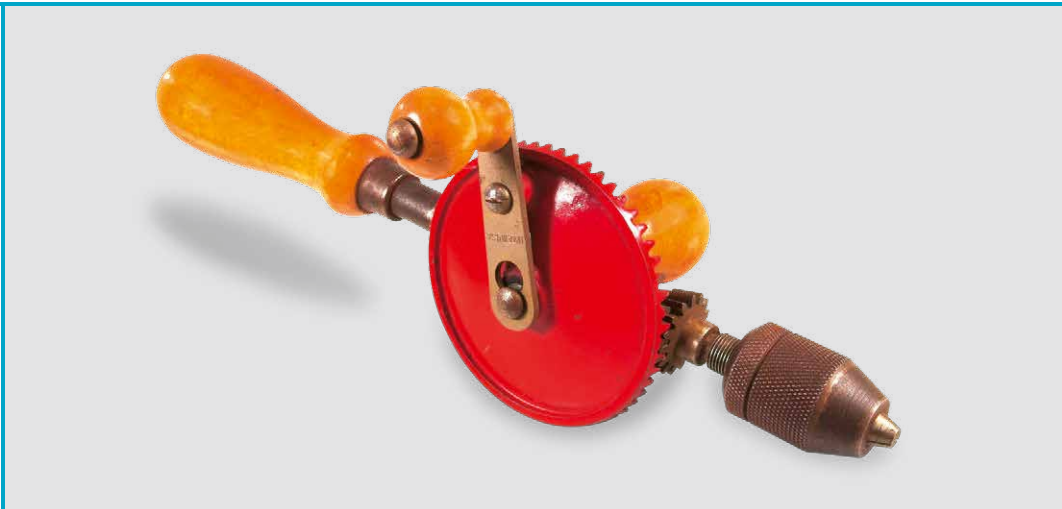
F1

This model uses the threads of the worm gear to demonstrate the principle of the screw. As the handle is turned the screw moves the gear across the screw at a 90° angle. The speed movement is significantly reduced.



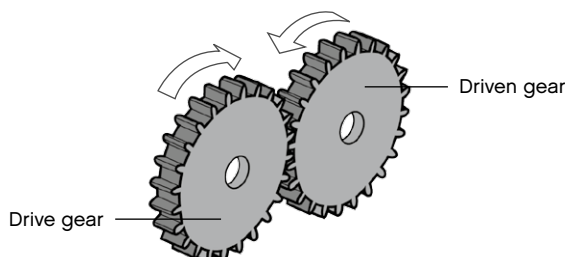
Gear

Student Worksheet



Mechanisms: Gear

Gears are wheels with teeth that mesh with each other. Because the teeth lock together, they can efficiently transfer force and motion.



The drive gear is the gear that is turned by an outside effort, for instance your hand or an engine. Any gear that is turned by another gear is called a driven gear or follower. The drive gear provides the input force and the driven gear delivers the output force.

Using a gear system can create change in speed, direction, and force. But there are always advantages and disadvantages. For example, you cannot have both more output force and an increase in speed at the same time.

To predict the ratio of which two meshed gears will move relative to each other, divide the number of teeth on the driven gear by the number of teeth on the drive gear. This is called the gear ratio. If a driven gear with 24 teeth is meshed with a drive gear with 48 teeth, there is a 1:2 gear ratio. That means the driven gear will turn twice as fast as the drive gear.

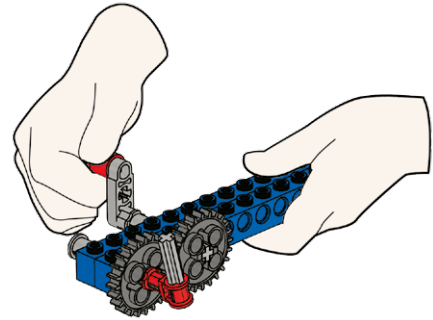
Gears are found in many machines where there is the need to control the speed of rotary movement and turning force. Common examples include power tools, cars, and egg beaters!

Did you know?

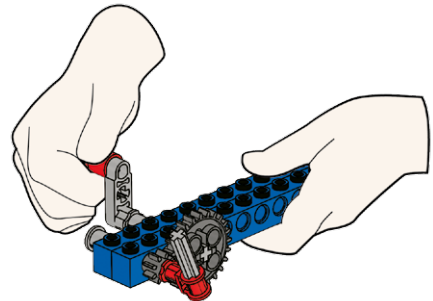
Not all gears are round. Some gears are square, triangular, and even elliptical.

G1**Build G1 book III, page 2**

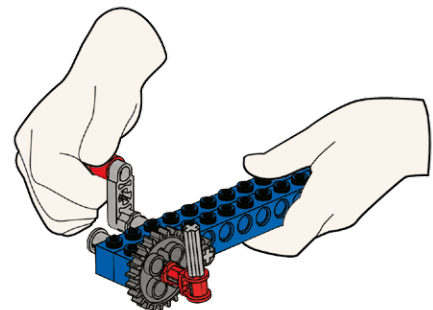
Turn the handle and describe the speeds of the drive and the driven gears. Circle and label the drive and driven gears.

**G2****Build G2 book III, page 3**

Turn the handle and describe the speeds of the drive and driven gears. Circle and label the drive and driven gears.

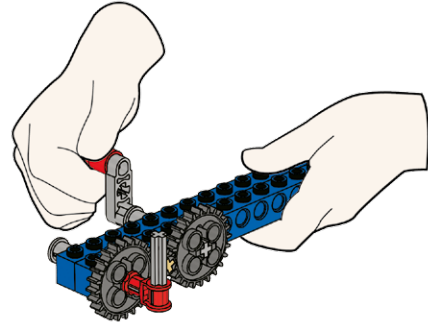
**G3****Build G3 book III, page 4**

Turn the handle and describe the speeds of the drive and driven gears. Circle and label the drive and driven gears.

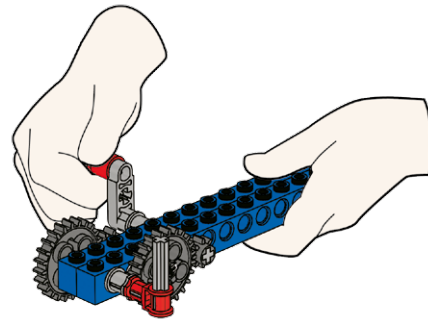


G4**Build G4 book III, page 5 to 6**

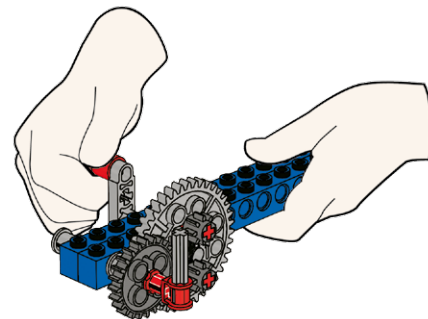
Turn the handle and describe the speed and direction of the drive and driven gears. Circle and label the drive and driven gears.

**G5****Build G5 book III, page 7 to 8**

Turn the handle and describe the speed and direction of the drive and driven gears. Circle and label the drive and driven gears.

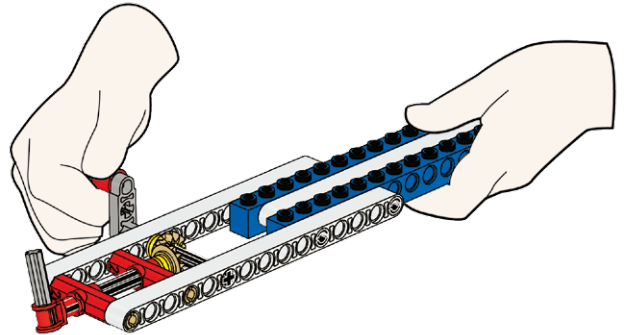
**G6****Build G6 book III, page 9 to 10**

Turn the handle and describe the movement of the driven gear.



G7**Build G7 book III, page 11 to 14**

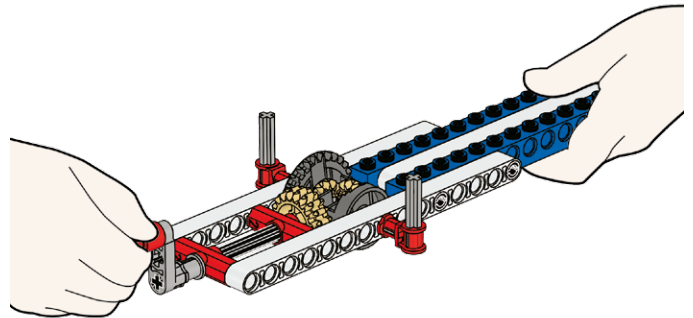
Turn the handle and describe what happens.

**G8****Build G8 book III, page 15 to 18**

Turn the handle and describe what happens.

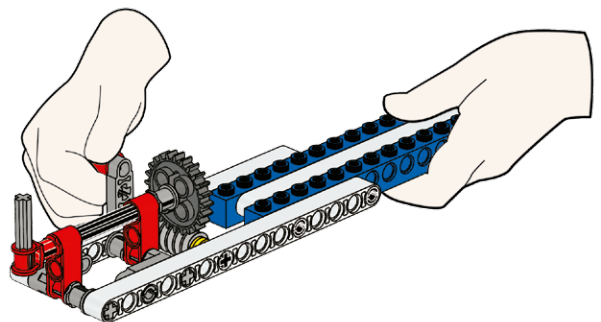
What happens if you stop one of the output pointers?

What happens if you stop both output pointers?

**G9****Build G9 book III, page 19 to 22**

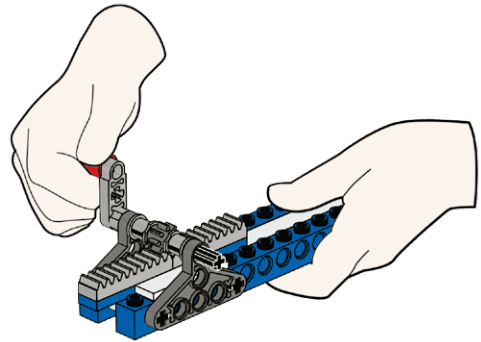
Turn the handle and describe what happens.

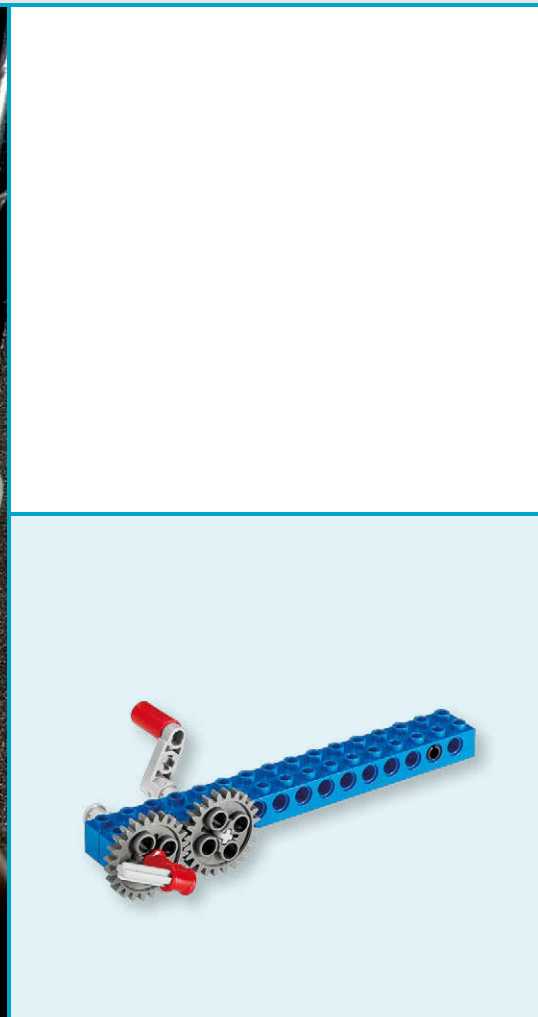
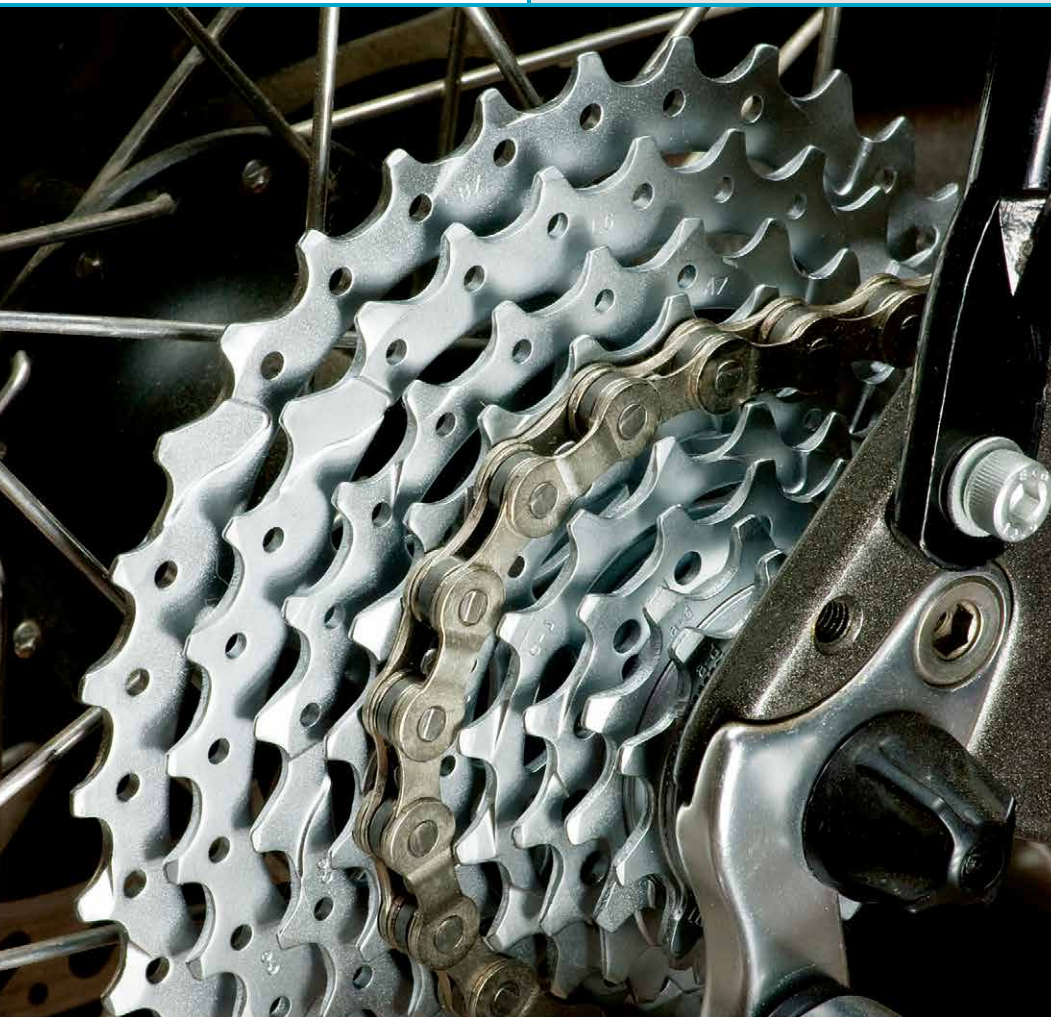
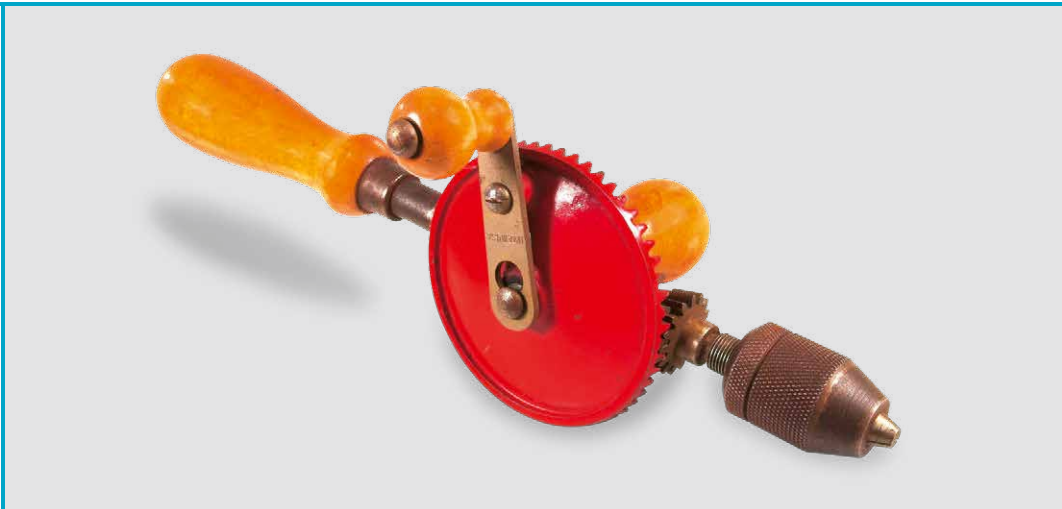
What happens if you try turning the output pointer?



G10**Build G10 book III, page 23 to 25**

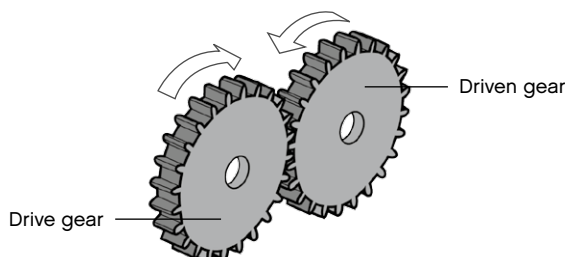
Turn the handle and describe what happens.





Mechanisms: Gear

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To determine the ratio of which two meshed gears will move relative to each other, divide the number of teeth on the driven gear by the number of teeth on the drive gear. This is called the gear ratio. If a driven gear with 24 teeth is meshed with a drive gear with 48 teeth, there is a 1:2 gear ratio. That means the driven gear will turn twice as fast as the drive gear.

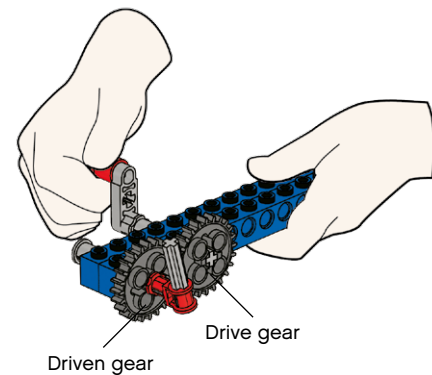
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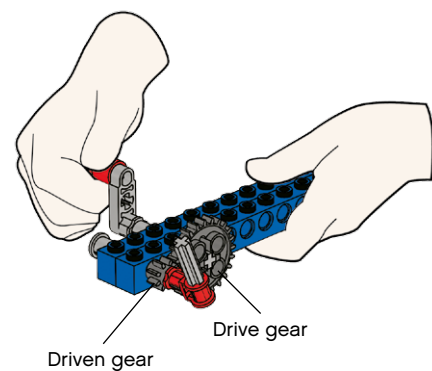
Not all gears are round. Some gears are square, triangular, and even elliptical.

G1

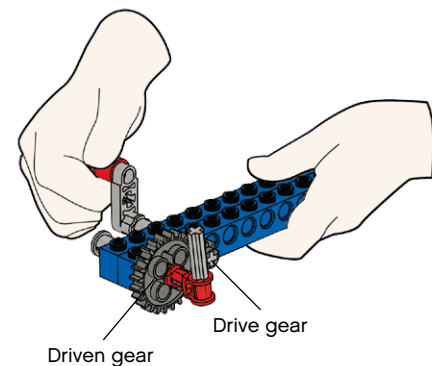
This model shows a 1:1 gear ratio. The speeds of the drive gear and the driven gears are the same, because they have the same number of teeth. The drive and driven gears turn in opposite directions.

**G2**

This model shows gearing up. The larger drive gear turns the smaller driven gear, resulting in increased speed, but reduced output force.

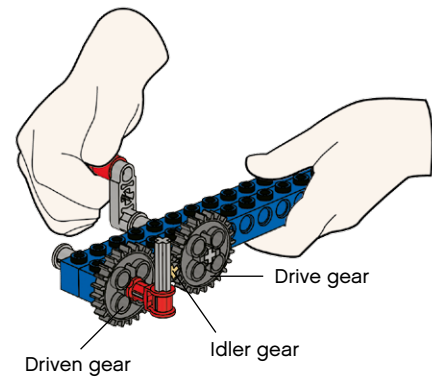
**G3**

This model shows gearing down. The smaller drive turns the larger driven gear, resulting in reduced speed, but increased output force.

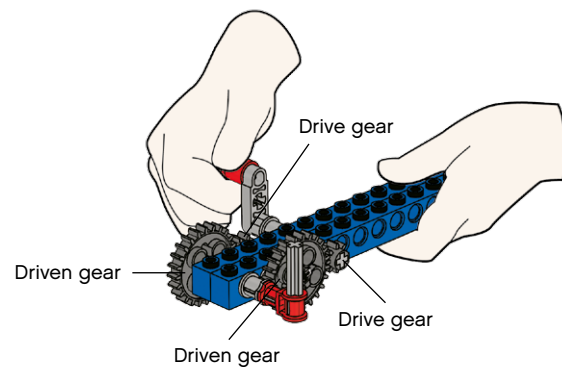


G4

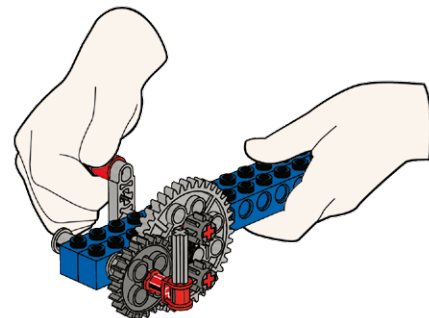
This model shows an idler gearing. The small gear is an idler gear. The idler gear does not affect the speed or output force of either the drive or the driven gears. The drive and the driven gears turn in the same direction and at the same speed.

**G5**

This model shows an example of compound gearing. Because of the way this compound gearing is arranged, the turning speed is significantly reduced and the output force greatly increased. The smaller drive gear slowly turns the larger driven gear. The smaller gear on the same axle as the driven gear is now set in motion and slowly turns the second large driven gear, making it turn even more slowly.

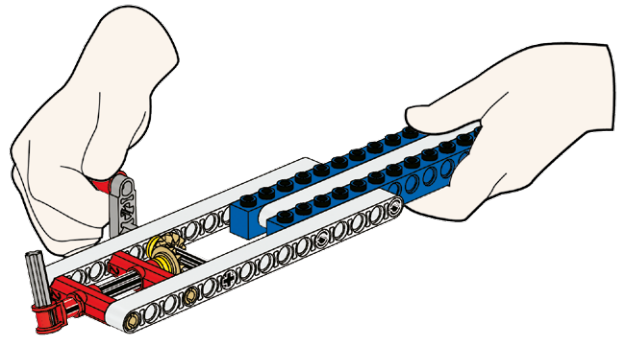
**G6**

This model shows gears set up for periodic movement: the driven gear turns for a short while and then stops for a moment. Speed is significantly reduced as movement only occurs when the driven gear is meshed with one of the two drive gears.

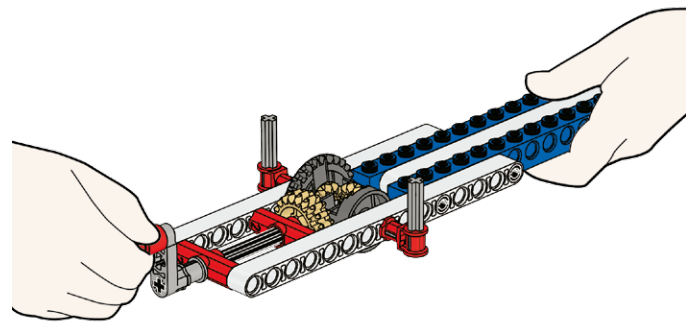


G7

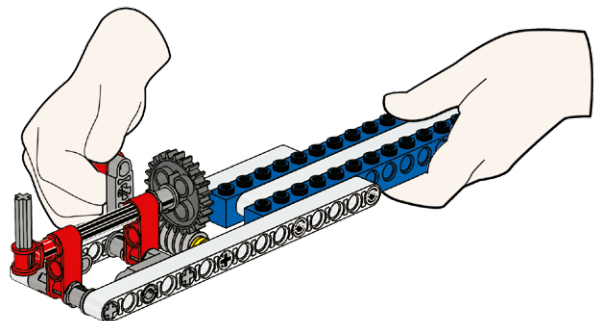
This model shows an angle gearing. The two meshed bevel gears transfer the speed and force unchanged, but at an angle of 90° .

**G8**

This model shows a differential gearing. The input force is transferred to two output forces at an angle of 90° . When one output pointer is stopped, the other will double its original speed. When both output pointers are stopped the handle cannot be turned.

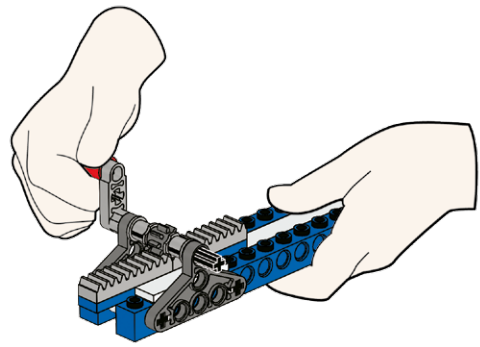
**G9**

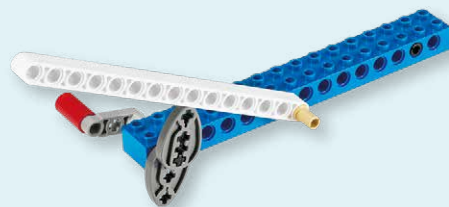
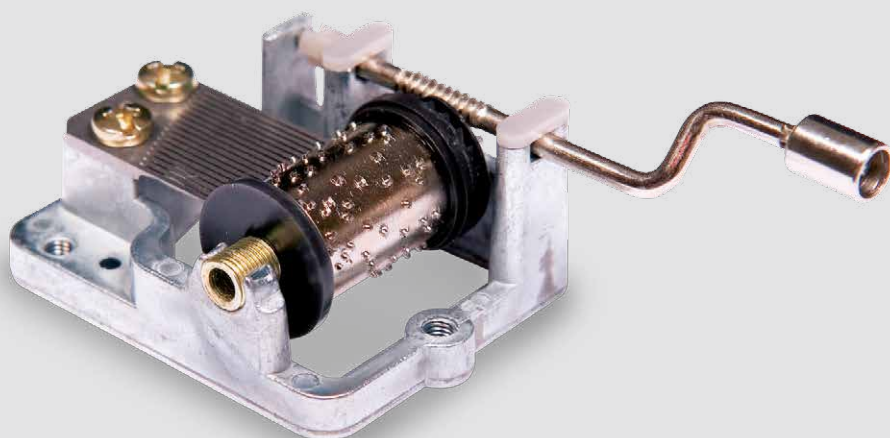
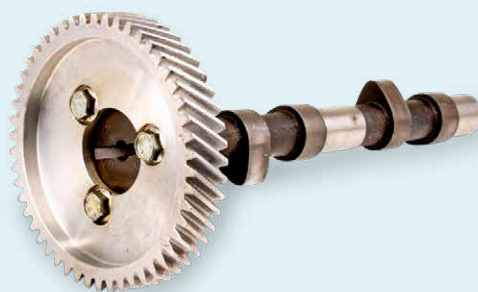
This model shows a worm gear. It reduces speed significantly as it takes a complete turn of the worm gear to move the gear above by a single tooth. It changes direction by 90° . The output force is increased significantly. Worm gears can only be used as a drive gear.



G10

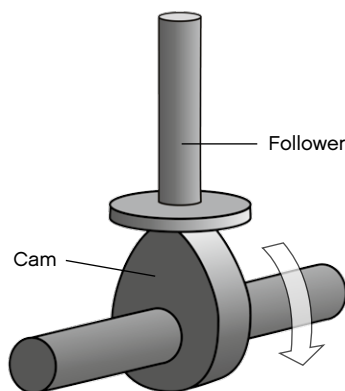
This model shows a rack and pinion gearing. Unlike the previous gears a rack and pinion gearing can only be used for linear motion, not rotary. When the handle is turned the gear rack moves forward or backwards depending on the rotational direction of the small gear (called a pinion).





Mechanisms: Cam

A cam is a shaped frame turning about an axis, like a rotating wheel.



The profile of a cam allows it to control the timing and degree of movement of a follower. A cam can also be regarded as a continuous, variable inclined plane. Cams can be circular, pear shaped, or irregular.

Cams and cam followers are very prone to wear due to friction. Cam followers often have tiny rollers attached to them to reduce this friction.

Common applications with cam mechanisms include an electric toothbrush, an engine camshaft, and clamps.



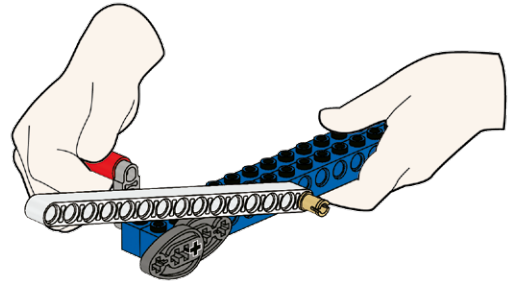
Did you know?

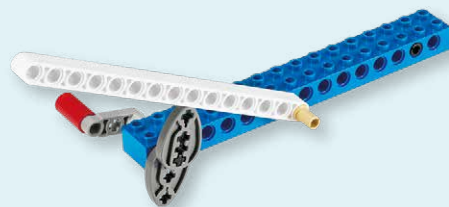
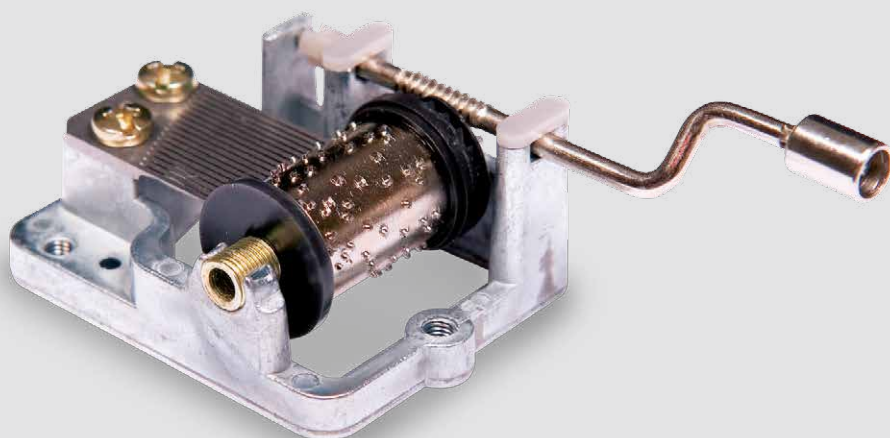
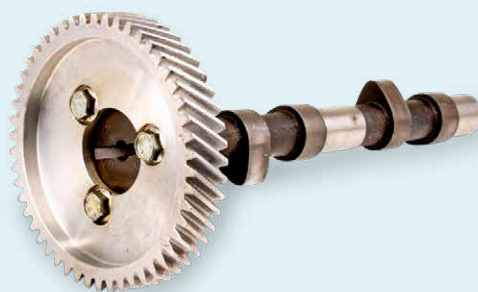
Spring-loaded cams are used by rock climbers to tightly grip rock crevices so that they can then attach climbing ropes.

H1

Build H1 book III, page 26 to 27

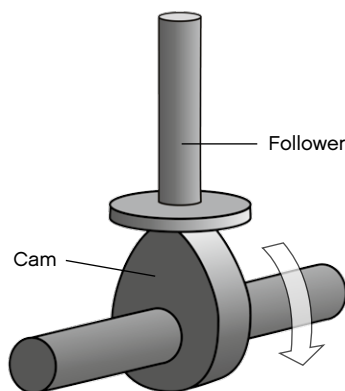
Turn the handle and describe the movement of the follower.





Mechanisms: Cam

A cam is a shaped frame turning about an axis, like a rotating wheel.



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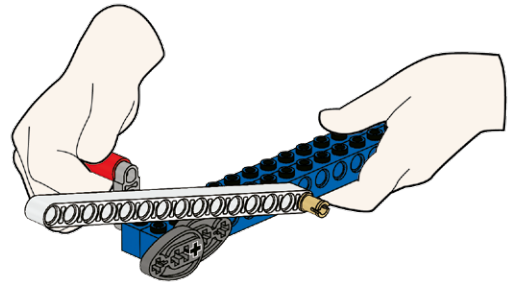


Did you know?

Spring-loaded cams are used by rock climbers to tightly grip rock crevices so that they can then attach climbing ropes.

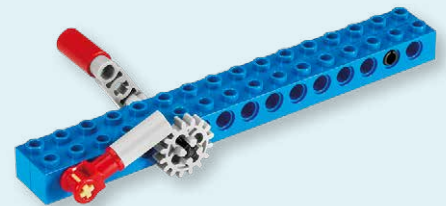
H1

This model shows a double cam mechanism. As the two cams rotate, their shape and size dictate a sequence of upward and downward movements of the follower.



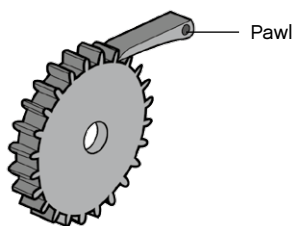
Pawl and Ratchet

Student Worksheet



Mechanisms: Pawl and Ratchet

A ratchet mechanism is based on a gear wheel and a pawl that follows as the wheel turns.



When the gear is moving in one direction, the pawl slides up and over the gear teeth, sending the pawl into the notch before the next tooth. The pawl is then jammed against the depression between the gear teeth, preventing any backwards motion.

Ratchet mechanisms are very useful devices for allowing linear or rotary motion in only one direction.

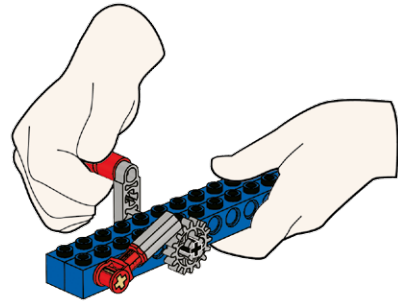
Common examples of ratchets are clocks, jacks, and hoists.

Did you know?

There are ratchets in some screw drivers that allow the user to turn with an effort in one direction and then turn back without turning the screw.

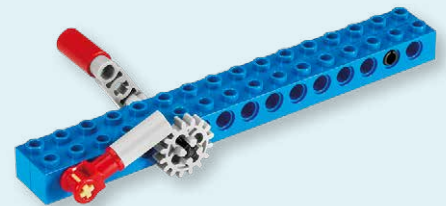
I1**Build I1 book III, page 28 to 29**

Turn the handle in both directions and describe what happens.



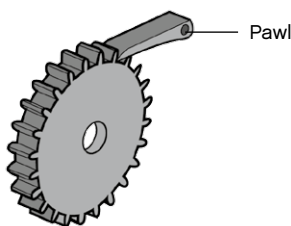
Pawl and Ratchet

Teacher's Notes



Mechanisms: Pawl and Ratchet

A ratchet mechanism is based on a gear wheel and a pawl that follows as the wheel turns.



When the gear is moving in one direction, the pawl slides up and over the gear teeth, sending the pawl into the notch before the next tooth. The pawl is then jammed against the depression between the gear teeth, preventing any backwards motion.

Ratchet mechanisms are very useful devices for allowing linear or rotary motion in only one direction.

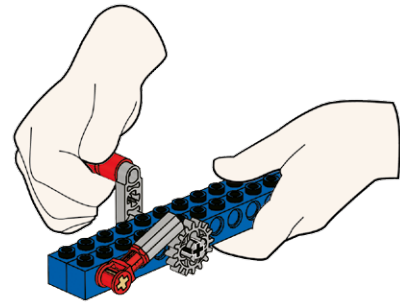
Common examples of ratchets are clocks, jacks, and hoists.

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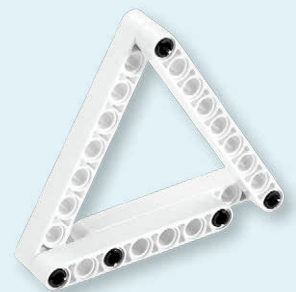
I1

This model shows a pawl and ratchet gearing. When the handle is turned in one direction, the pawl slides up and over the gear teeth, sending the pawl into the depression before the next tooth. When the handle is turned in the opposite direction, the pawl stops the movement.



Structures

Student Worksheet

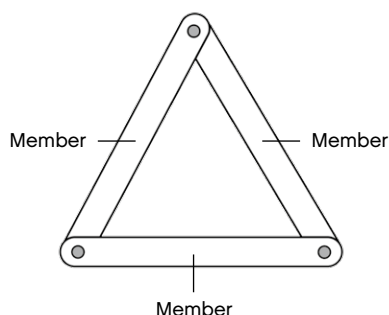


Structures

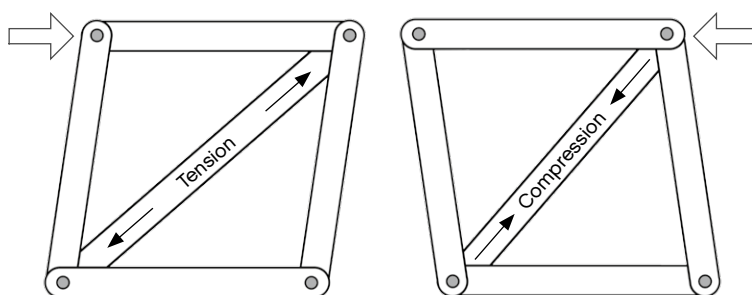
A structure is a construction in which individual parts are arranged to form a whole. All structures are under the influence of external and internal forces. Examples of external forces acting on a structure include the wind or the weight of trucks and buses passing over a bridge. An internal force could be the weight of a roof or the shaking of a large diesel engine on its mountings. Choice of materials will affect the safety level of a structure.

Did you know?

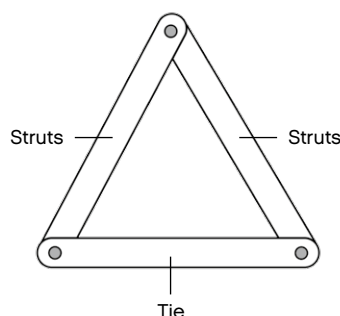
In bridges, cranes, towers and even space stations, triangulation is often used to make structures rigid.



A frame structure is made from pieces called members. This frame is rigid because it is triangulated.



The forces that act on members are called tensile forces or compression forces. Tensile forces will stretch the structure and compression forces will squeeze the structure.

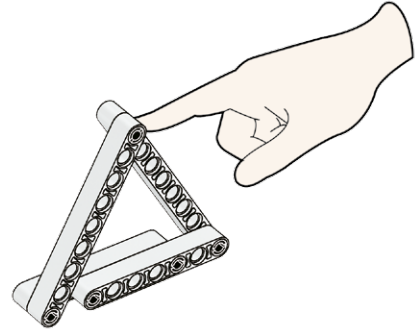


Members that are in tension are called ties; members that are under compression are called struts.

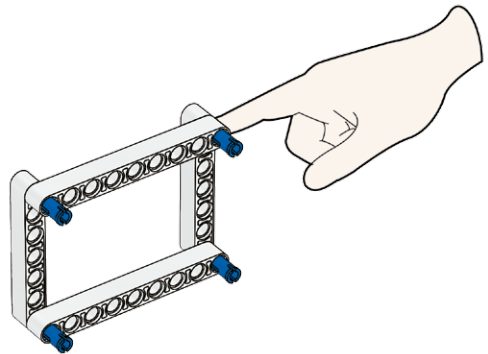
Common examples of structural principles can be found in scaffoldings, buildings and bridges.

J1**Build J1 book III, page 30**

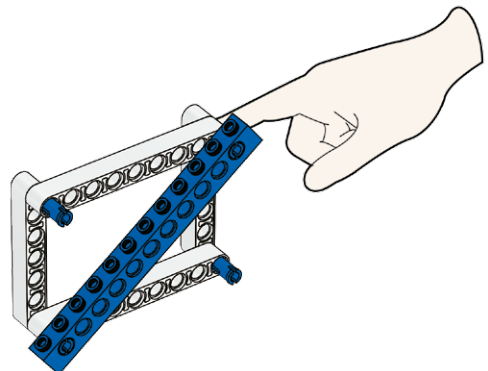
Push to create compression forces and pull to create tension forces on the members of the triangular frame. Describe what happens.

**J2****Build J2 book III, page 31**

Push and pull to create tensile or compression forces on the members of the rectangular frame. Describe what happens.

**J3****Build J3 book III, page 32**

Add the cross member and push and pull the rectangular frame to create tensile forces or compression forces. Describe what happens.



Structures

Teacher's Notes



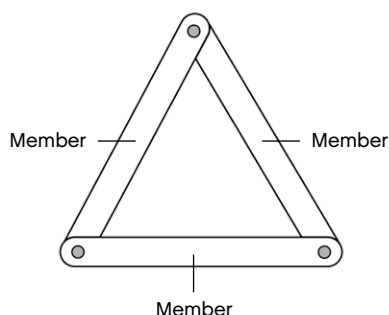
Structures

A structure is a construction in which individual parts are arranged to form a whole. All structures are under the influence of external and internal forces. Examples of external forces acting on a structure include the wind or the weight of trucks and buses passing over a bridge. An internal force could be the weight of a roof or the shaking of a large diesel engine on its mountings. Choice of materials will affect the safety level of a structure.

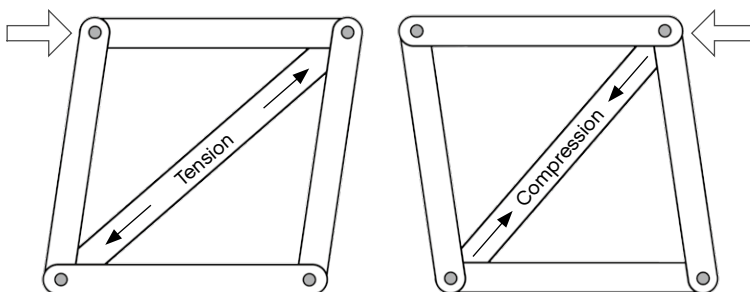


Did you know?

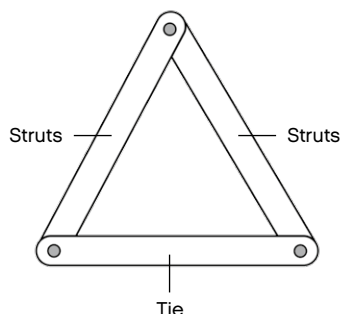
In bridges, cranes, towers and even space stations, triangulation is often used to make structures rigid.



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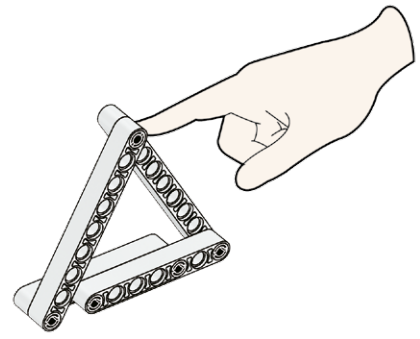


Members that are in tension are called ties; members that are under compression are called struts.

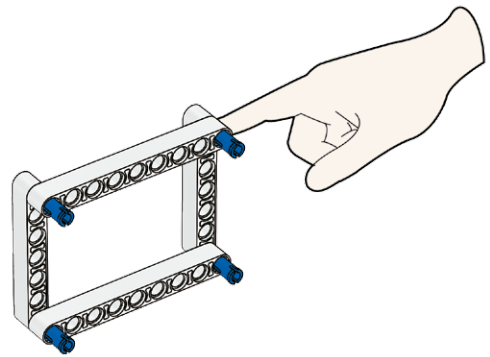
Common examples of structural principles can be found in scaffoldings, buildings and bridges.

J1

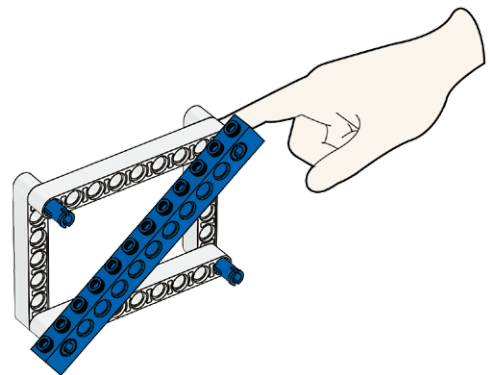
This model shows a triangular structure. When the triangular frame is pushed or pulled the shape doesn't change. The triangular frame is rigid.

**J2**

This model shows a rectangular structure. The rectangular frame is easily changed when pushed and pulled. A rectangular frame is not rigid.

**J3**

This model shows a rectangular structure supported by a cross member. The rectangular frame is prevented from changing when pushed and pulled by the cross member. The cross members makes the rectangular frame rigid.





Sweeper

Technology

- Using mechanisms – bevel gears, gearing up, pulleys
- Testing before making improvements
- Safety systems

Science

- Measuring distance
- Friction
- Scientific investigations

Vocabulary

- Efficiency
- Gearing up
- Slip
- Pulley
- Belt
- Friction
- Bevel gear

Other Materials Required

- A large cardboard box or a low card wall to stop flying trash, approx. 60 x 40 cm (≈ 24 x 16 in) is ideal
- For trash: use crumpled scraps of paper, LEGO® connector pegs, bushings, crushed real leaves, or the like



Tip:

Don't use seeds or beads as they could hit someone in the eye.

Connect

The path is covered in trash and leaves. It looks terrible and could be dangerous if someone slips on it! Now Jack and Jill have the job of cleaning it up, but they are not keen on their brooms and would much rather play on their cart.

Zog the Dog tries to help out but he's not very good at it.

Suddenly they get an idea about combining the broom with the cart, but they are not sure exactly how to make it work.

How can you combine pushing a cart with cleaning a path?
Let's find out!



Construct

Make the Test Park

Use a smooth tabletop or floor, and place your crumb-proof wall or box on it.

Evenly spread out strips of crumpled paper scraps across a 10 cm (\approx 4 in) wide and 60 cm (\approx 24 in) long section of your park. This is the path covered in litter.

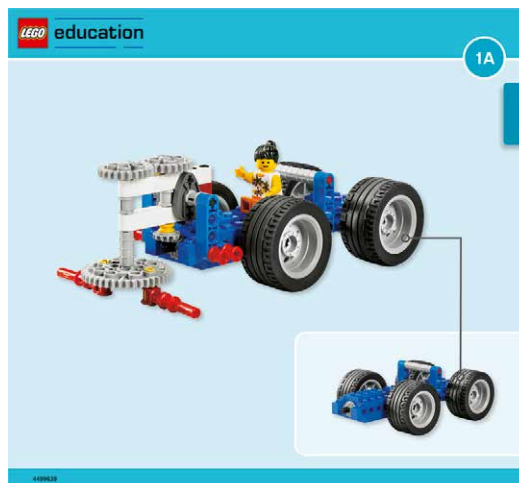
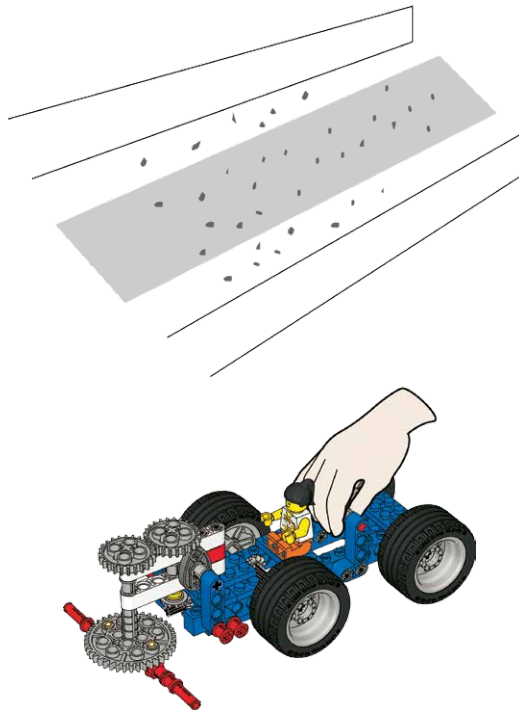
Leave plenty of room on either side of the path for the scraps to fly!

Build the Sweeper

(All of book 1A and book 1B to page 8, step 11)

Test That It Runs Smoothly

Push it gently across the table. The spinner should spin freely without hitting the frame of the cart and the sweeper 'blades' should open out and spin without touching the table.



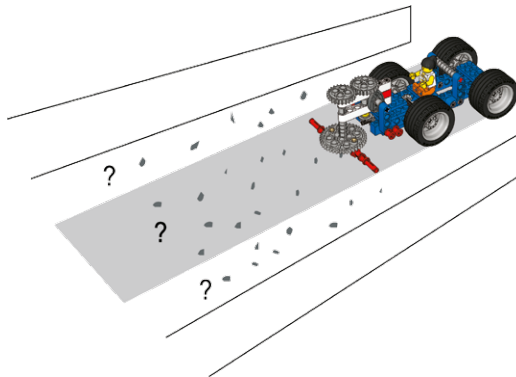
Contemplate

How well does it sweep?

Push it along the dirty path. How much of the scraps did you sweep aside? A quarter? Half?

What problems are there with this design? Estimate the amount swept aside compared to what is left on the strip.

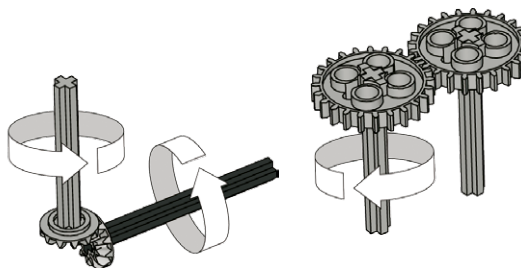
It is not a fast sweeper and it doesn't actually pick up the scraps!



What is the gearing of the sweeper?

Push the sweeper along so the cart's wheels turn once. How many times does the sweeper head turn? Can you explain?

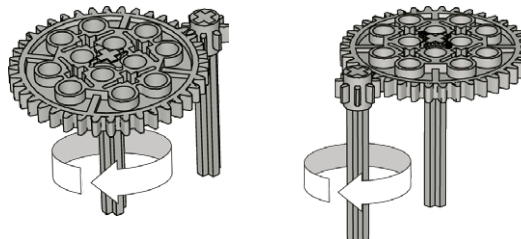
The sweeper head turns once. The gearing is 1:1. All the bevel and spur gears that mesh with each other are the same size. So there is no change in speed.



How can we make it sweep faster?

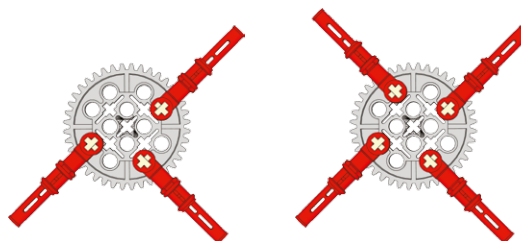
Try different combinations of drive gears (step 12, step 13).

Step 12 makes the sweeper head far too slow, step 13 makes it 5 times as fast. Note the 40-tooth gear driving the 8-tooth gear!



Jack and Jill would like to finish the job as quickly as possible so no one will fall over in the leaves and hurt themselves. To help them, try adding more blades to the sweeper head (step 14).

Three blades make it unbalanced and even worse than 2 blades. Four blades is better, and in balance.



Danger!

Push the sweeper and hold the sweeper head. What happens and what problems could this lead to?

The wheels may lock and the gears jump. Any items getting stuck in the sweeper may overload the machine or break the gears.

Did you know?

All the gears with regular teeth, like the big gear, are called spur gears.

Tip:

What do the bevel gears do? They turn the direction of movement through 90°. They send moving energy around corners!

Continue

A Safer Sweeper

Rebuild the model to be driven by pulley belts. Try out different pulley systems. Predict and test how fast they will spin and how well they will sweep.

The sweeper head usually rotates more quickly. The bigger the driver pulley, the faster the rotation. It is harder to push though as there is more friction on the axles.

Push the sweeper and hold the sweeper head again. What happens? What are the pros and cons?

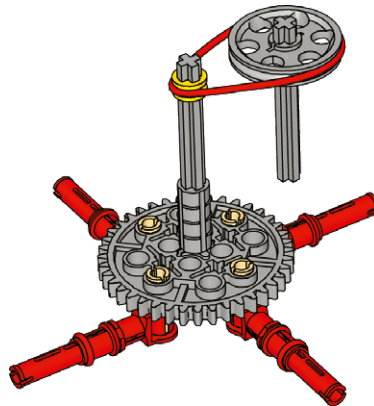
The driving band slips.

Good Points:

The sweeper will stop if something jams in it. It could be safer for the operator too.

Bad Points:

It takes more energy to push.



A Dirt-Collector

Can you work out a way to not only remove the trash from the path, but also collect it?

Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Sweeper

Name(s): _____

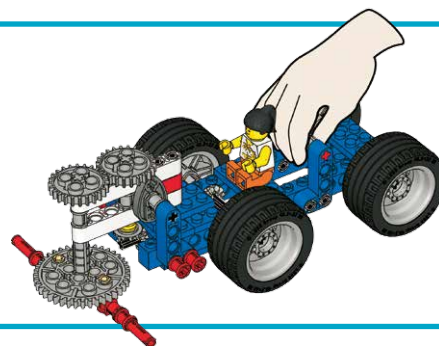
How can you combine pushing a cart
with cleaning a path?
Let's find out!



Build the Sweeper

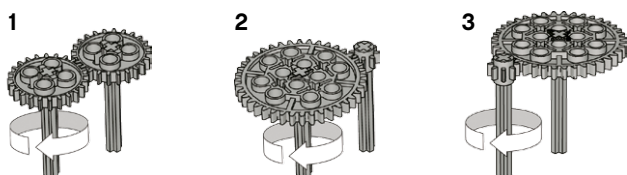
(all of book 1A and book 1B to step 11)

- Try it
- If it does not spin smoothly loosen the axle bushings and make sure the bricks are firmly linked to one another

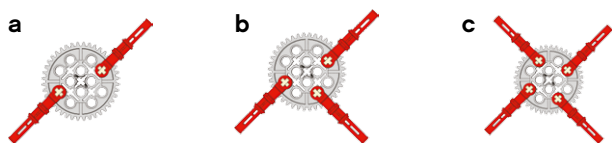


What makes a good sweeper?

- Test your spin speeds with the gears shown below. Try them with only two sweeper blades (a).



- Now try these sweeper blades with your FASTEST gears to see which one is best at sweeping crumbs





- Test different sweepers and compare them with your standard model

Tip: Write the words on the right into the boxes above. You can use them more than once. Make up your own descriptions too.

I Tried This	My Prediction	What happened?
1a		
2a		
3a		

The same Faster
Worse Slower Better

A Safer Sweeper

	Prediction	What happened?
		
		



Also try:

- Holding the sweeper blades while you push the sweeper
- Cleaning up crumbs from a carpet

My own discoveries:

[illegible]

My Amazing Table Sweeper

Draw and label your sweeper design.
Explain how the three best parts work.





Figure 1 consists of nine scatter plots arranged in a 3x3 grid. The rows represent three countries: USA (top), Canada (middle), and Australia (bottom). The columns represent three years: 1990 (left), 2000 (middle), and 2010 (right). Each plot shows the relationship between the number of children in the household (x-axis) and the number of children in the family (y-axis). The x-axis ranges from 0 to 10, and the y-axis ranges from 0 to 10. The plots show a positive correlation between the two variables. The USA plots show a steeper slope than the Canada and Australia plots. The 1990 plots show a steeper slope than the 2000 and 2010 plots. The 2010 plots show a steeper slope than the 1990 plots.

Country	Year	Number of children in the household	Number of children in the family
USA	1990	0	0
		1	1
		2	2
	2000	0	0
		1	1
		2	2
	2010	0	0
		1	1
		2	2
Canada	1990	0	0
		1	1
		2	2
	2000	0	0
		1	1
		2	2
	2010	0	0
		1	1
		2	2
Australia	1990	0	0
		1	1
		2	2
	2000	0	0
		1	1
		2	2
	2010	0	0
		1	1
		2	2

Sweeper

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we drew, labeled, and explained how our sweeper works.				
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	<ul style="list-style-type: none"> We drew and labeled the parts of the sweeper. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We labeled three important parts of our sweeper. We explained how one of these parts works to help our sweeper clean the path. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We explained how all three of the parts we identified work to help our sweeper clean the path. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We suggested at least one improvement to our design to help Jack and Jill clean their path more effectively. <div style="text-align: center;"><input type="checkbox"/></div>
2. Student work related to this Practice: In this project, we explained what we discovered after we built a 'safe sweeper'.				
Constructing Explanations: Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	<ul style="list-style-type: none"> We changed our model to include two pulleys to make our sweeper blade turn. We explained what we observed when we held the sweeper blade. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We used our observations to help us explain why a sweeper blade that uses pulleys is safer than one that uses gears. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We tried our sweeper on a different surface such as a carpet with crumbs. We explained at least one advantage and one disadvantage of the pulley design. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We shared at least one new discovery from our observation that would help Jack and Jill clean their path more effectively. <div style="text-align: center;"><input type="checkbox"/></div>
3. Student work related to this Practice: In this project, we made a model to test how different sweeper blades could help Jack and Jill clear their path.				
Developing and Using Models: Use a model to generate data to test ideas about designed systems.	<ul style="list-style-type: none"> We built a model with wheels that could be pushed by hand to clear the path. The wheels on our sweeper turned the gears. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. Our wheels and gears caused the sweeper blades to turn. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We tested all three of the sweeper blades shown on our worksheet. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We invented at least one new sweeper blade to test. <div style="text-align: center;"><input type="checkbox"/></div>
Notes:				



Fishing Rod

Technology

- Using mechanisms – pulleys and levers
- Investigating a pawl and ratchet
- Designing and making a game

Science

- Forces
- Machines that make work easier
- Properties of materials
- Scientific investigation

Vocabulary

- Pulley block
- Ratchet
- Pawl
- Reel
- Effort
- Load

Other Materials Required

- Cardboard – big poster size
- Scissors
- Assorted color markers

Connect

Jack and Jill are at a friend's birthday party with some other children. They are in the garden and they have been selected to catch fish in the new Fishing Pond.

They have great fun, when suddenly Jack catches the largest and heaviest fish in the pond. Even using all his strength, he can't reel in the heavy fish.

Jill gets an idea as to how to reel in the fish. What do you think she plans on doing?

**How can we make an exciting fishing device for Jack and Jill, and land the large fish?
Let's find out!**



Construct

Build the Fishing Rod (including Pulley Block) and Fish

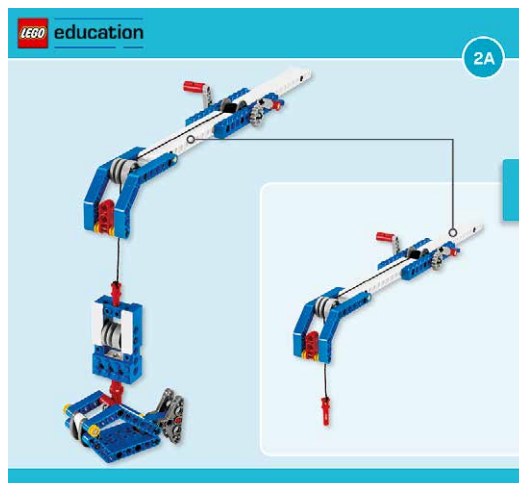
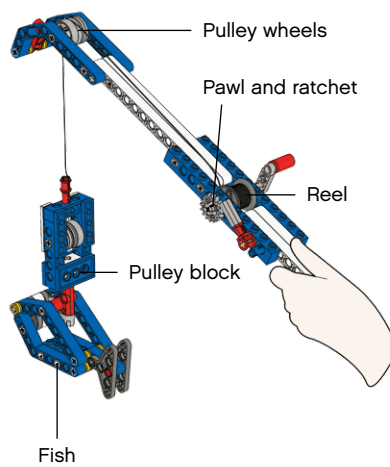
(all of book 2A and book 2B to page 10, step 19)

Fine-Tune Your Fishing Rod

Loosen any overly tight bushings so that the reel and pulleys roll freely. If not, the tests will not work properly.

Test to See If You Can Catch the Fish

You may need more than one attempt. Try catching a fish and releasing it from the hook several times.



Contemplate

Why use a reel and ratchet?

Try first lifting the large fish by simply pulling on the line. Then, lift using the reel. What do you notice?

Try the pawl and ratchet safety system (book 2A, page 10, step 19).

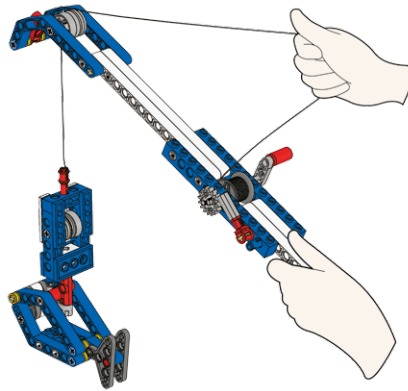
What are the advantages?

The reel makes it easier to lift the fish.

But it is slower than pulling the line by hand.

The ratchet locks the reel if you stop winding.

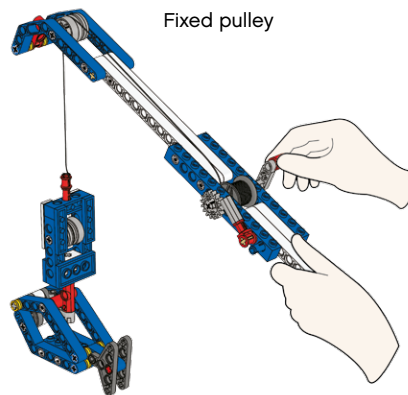
This is a safety system.



What difference does an extra pulley make?

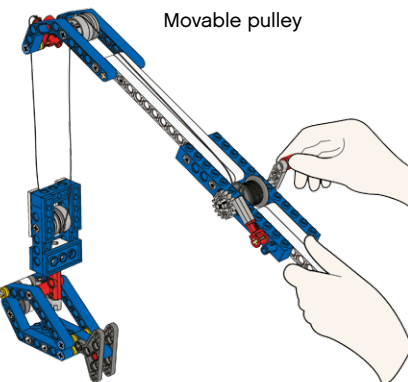
Set up the Fishing Rod as illustrated here. Predict and test which effects this might have when landing fish?

It actually feels heavy. This is because the second pulley is not being used – it is a fixed pulley. Pulleys are dead weight unless they are properly connected!

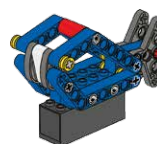


String up the pulley block as shown on page 11, step 20. Predict and test what effects this setup might have when landing the fish?

Even the heaviest fish is easier to lift. Using two pulleys – one fixed and one movable – means only half the effort is needed to lift the fish. But it is slower to reel in and you need to wind in twice as much line to reel in the fish.



Add a load (the weight element) to the fish and test again with your Fishing Rod. Find out which is the easier way to land the heavy fish.



Did you know?
Big cranes use this system to lift heavy loads with small motors. Some pulley systems, also called a block and tackle, use up to six or more pulley wheels!

Did you know?
The weight element contains steel plates and weighs exactly 53 g!

Continue

Design and Make Your Own Crazy Fishing Game

In the shortest possible time catch as many 'fish' as you can.

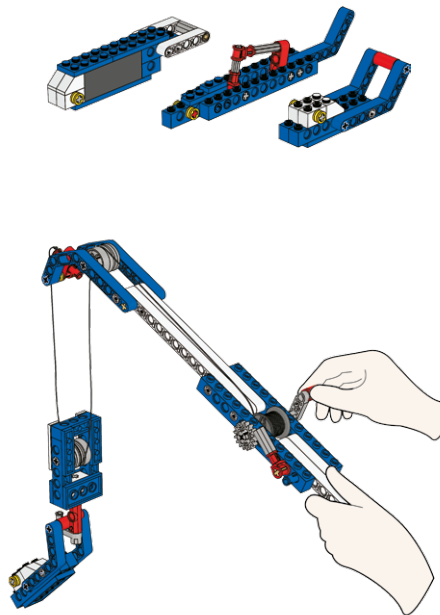
Build a variety of 'crazy fish' as shown. Invent more of your own. Maybe you can make them look more like real fish?

Hook them and see which are easy and which are more difficult to catch.

Agree on rules and a scoring system for your fish. Which designs would trigger a higher score if a fish is landed?

Play a timed game. What score did you get in 60 seconds?

Try again. How much did your score improve with each new attempt?

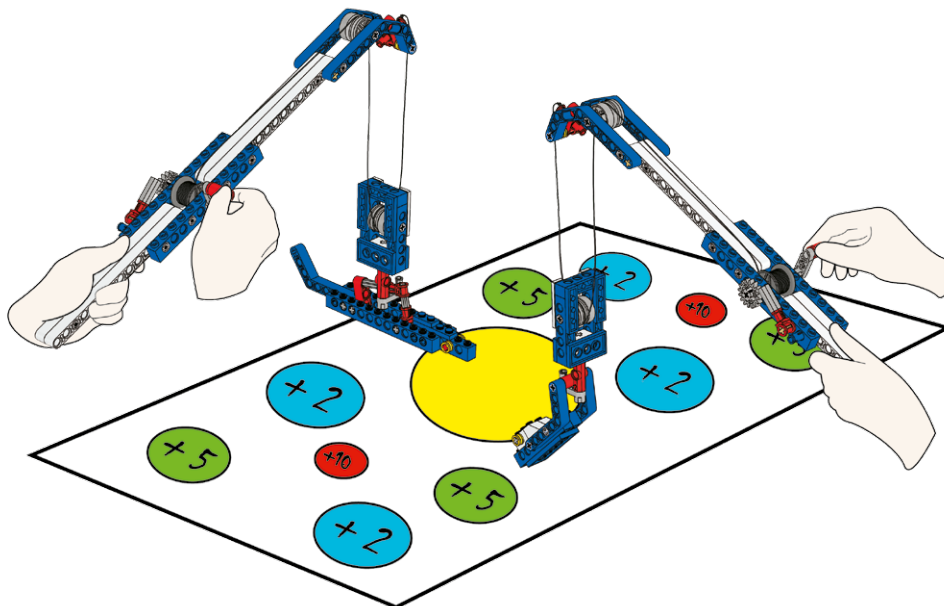


Extra Challenge: Sorting Fish

Design a game board with different sized targets or 'baskets' in which to place the fish.

Work out additional scores for successfully landing a fish in a basket.

Ask another team to join in the great 'fishing game'.



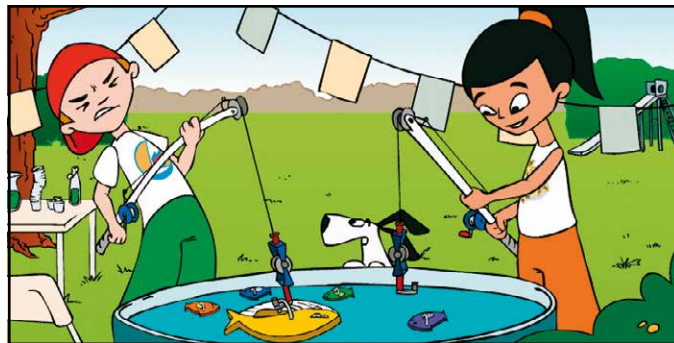
Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
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a	to explore its limitations.										
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a	that included independent and dependent variables and controls.										
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c	that tested the accuracy of various methods for collecting data.										
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a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
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c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Fishing Rod

Name(s): _____

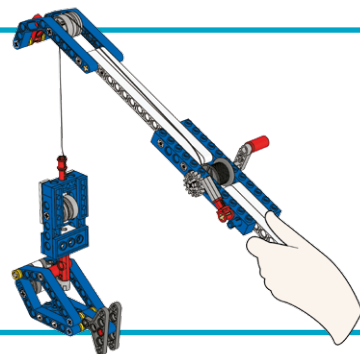
How can we make an exciting fishing device for Jack and Jill and land a big fish?
Let's find out!



Build the Fishing Rod (including Pulley Block) and Fish

(all of book 2A and book 2B to page 10, step 19)

- Make sure the reel and pulleys spin as freely as possible.



Which features of your rod make it easier to land a big fish?

Predict and test:

- How much **effort** you need to lift the fish each time?
- How much **time** you need to lift each fish?
- Which is the **fastest** reel?
- Which is the **slowest** reel?
- Try using the ratchet.

Small effort

Very slow

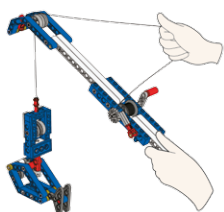
Fast

Medium effort

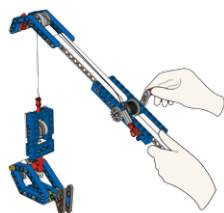
Slow

Big effort

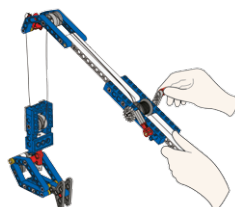
Tip: Write these words in the boxes.
You can use them more than once.



– by hand and with **one** fixed pulley



– with reel and **one** fixed pulley



– with reel and **two** pulleys;
one fixed and one movable pulley

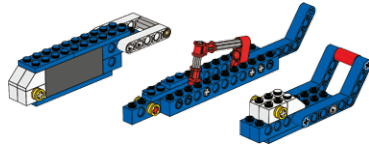
	My Prediction	What happened?	Actual Speed

Block and Tackle

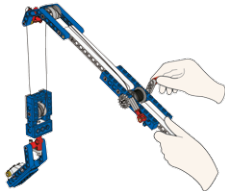
A block and tackle is a system of pulleys that is used to lift very heavy objects with a minimum of effort.

Design and Make Your Own Crazy Fishing Game

Build a variety of 'crazy fish' as shown. Invent more fish of your own.



Hook them and see which are easy and which are more difficult to catch. Catch as many 'fish' as possible in the shortest time.



Agree on rules and a 'scoring system' for your catch. Which designs would trigger a higher score if a fish is landed?

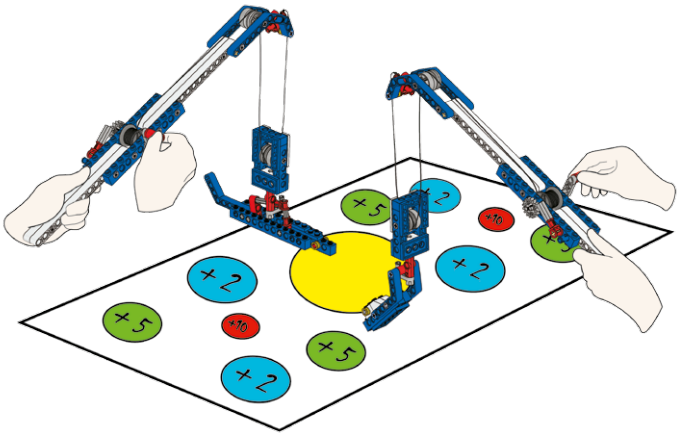
Play a game 'against the clock'. What score did you get in 60 seconds in attempts 1, 2, and 3?

1	2	3

Extra Challenge: Sorting Fish

Design a game board with different sized targets or 'baskets' in which to place the fish. Work out additional scores for successfully landing a fish in a basket.

Ask another team to join in the great 'fishing game'.







My Fishing Rod

Draw and label your very best rod design. Explain how the hook, crank, and pulleys work.

Fishing Rod

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a model to help Jack and Jill catch a big fish.				
Developing and Using Models: Use a model to generate data to test ideas about designed systems.	<ul style="list-style-type: none"> We built a fishing rod that can catch fish. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. Our fishing rod included a working reel and pulley. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. Our fishing rod included a fixed and moveable. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. Our fishing rod included a fixed and moveable. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we investigated how the different pulley designs in our fishing rod affect the effort and speed required to use the fishing rod.				
Planning and Carrying Out Investigations: Collect data about the performance of a proposed object under a range of conditions.	<ul style="list-style-type: none"> We made predictions and observations for at least two of the set-ups given on our worksheet. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We made predictions and observations for all three set-ups shown on our worksheet. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We used a stop watch and recorded how much time was need to reel in a fish for each set-up. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We used a ruler to measure how far our fish moved while we reeled them in. We calculated how fast we reeled in our fish using the speed equation, $\text{speed} = \text{distance}/\text{time}$. <input type="checkbox"/>
3. Student work related to this Practice: We labelled our best fishing rod. We explained how the parts of our fishing rod work separately and how they work together to catch fish.				
Systems and system models: Systems may have sub-systems and be a part of a larger complex system. Use models to present systems and their interactions such as inputs, processes, and outputs.	<ul style="list-style-type: none"> We labeled one important part of the fishing rod. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We labeled the hook, crank, and pulleys. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained how the hook, crank, and pulleys work as separate parts of the fishing rod 'system'. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We explained how the hook, crank, and pulleys work together in the fishing rod 'system' to catch a fish. <input type="checkbox"/>
Notes:				



Freewheeling

Technology

- Using mechanisms – wheels and axles
- Assembling components

Science

- Measuring distance
- Reading and calibrating scales
- Forces
- Moving energy
- Energy of position
- Friction and air resistance
- Scientific investigation

Vocabulary

- Mass
- Position
- Friction
- Efficiency
- Kinetic energy
- Potential energy

Other Materials Required

- 4 meters (\approx 4 yards) of smooth floor
- Masking tape
- Meter stick (yard stick) or measuring tape
- Plank of wood or shelf at least 1 meter (\approx 1 yard) long
- Pile of books or boxes to elevate the plank
- Spare LEGO® bricks for taking measurements
- Whiteboard marker
- Scissors

Connect

Jack and Jill are arguing as usual. They are making carts to see which one can roll the furthest down Launching Hill in their local Greenall Park.

Jill says that if she puts some extra weight (Zog the Dog) on her cart, she will roll further because the cart is heavier. Jack thinks that because heavy loads are hard to move, he will go further. He prefers to go for bigger wheels, but Jill is not so sure this approach will help.

**Which will roll further? Heavier or lighter carts, with bigger or smaller wheels?
Let's find out!**

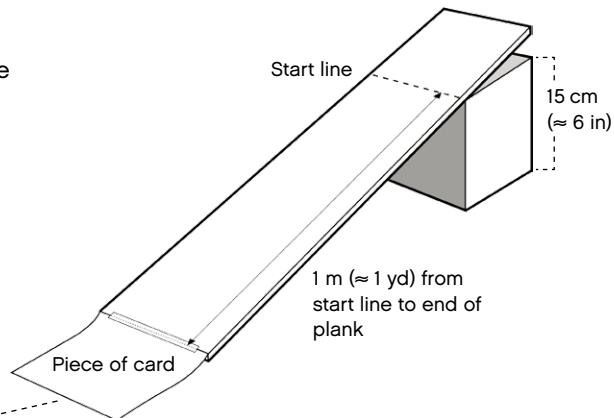


Construct

Make Launching Hill

Draw a start line, 1 meter (≈ 1 yard) from one end of the plank. Place a support so that the start line is 15 cm from the floor. Why do we need a start line?

We need it to ensure that all tests are fair; all carts should roll down exactly the same ramp.

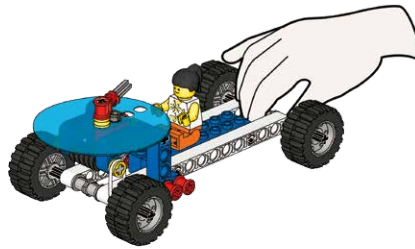


Approx. 4 m (4 yd)
of smooth floor

Build the Freewheeler

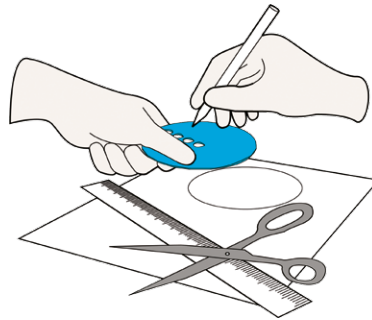
(all of book 3A and book 3B to page 6, step 12)

- Test the freewheeler on the ramp. Is the model running smoothly? If not, check all axles and bushings to make sure the wheels are turning smoothly. Also check that all elements are firmly linked to one another

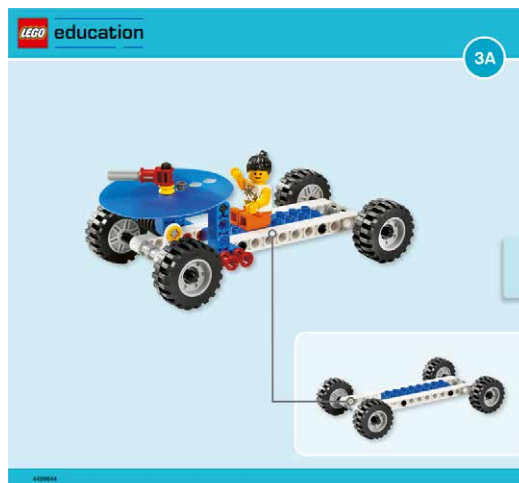


Trace the scale

Or cut out paper copies of the dial discs if you want to keep the original discs untouched.



Tip:
If the thickness of the plank causes the carts to bump down from it onto the floor, use a piece of card to make a smooth transition from plank to floor.



Contemplate

Measure how far the empty cart rolls. Measure with a meter stick (or a yard stick) and compare with the pointer and dial. Record the distance and use a LEGO® brick as a marker of where it stopped. Test at least three times to be sure you have made a scientifically correct answer.

An unloaded cart should roll about 160 cm (≈ 5.25 ft). This is more than once around the dial. The dial is accurate to within a few centimeters.

Trace the 1 m (≈ 1 yd) dial divisions on the plastic disc with an erasable whiteboard marker. Let the freewheeler go down the ramp again and see if it runs approximately 160 cm (≈ 5.25 ft) by looking at the dial and pointer (one full revolution of the disc and a little more than another half). Carry out several tests. There is no need to use rulers or measuring tapes – just use the readings on the dial.

Add a weight brick to the cart (book 3B, page 7, step 13). Predict how far it will roll this time by placing another marker brick along the track. Then test.

The cart will roll almost twice as far. The weight brick 'falling' with the cart gives it nearly twice as much moving energy. However, note too that extra weight creates extra friction or rubbing on the axles which slows down the cart.

What do you notice about the pointer?

The pointer goes around more than once. You will need to count how many times it goes around.

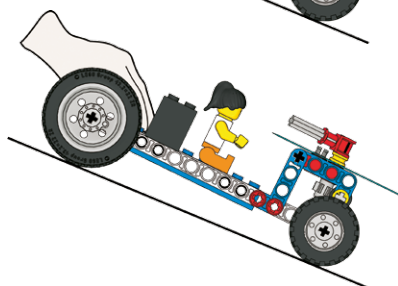
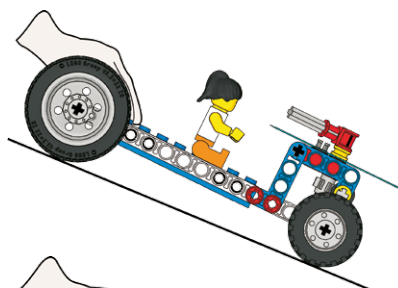
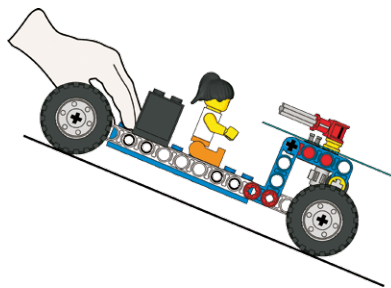
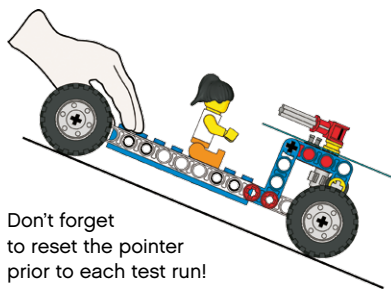
Test several times to make sure your findings are consistent.

Jack's Big Wheel Deal

Will big wheels help the cart to roll further than the smaller wheels? Fit them onto the rear axle and test on the ramp (book 3B, page 7, step 14).

First test unloaded (book 3B page 7, step 14), then test loaded (book 3B, page 8, step 15).

The cart usually rolls further. There are two reasons: more weight = more energy, and the rear axle turns more slowly, which means less friction.



Tip:

Note that the dial measures almost exactly 1m (≈ 1 yd) in one rotation. This means that the pointer is at zero when the cart hits the floor.



Did you know?

The empty cart weighs about 58 g (≈ 2 oz). And the weight brick weighs 53 g (≈ 1.9 oz)... almost the same!



Did you know?

The big wheels weigh 16 g (≈ 0.5 oz) each and the small ones only 6 g (≈ 0.2 oz) each.

Continue

Super Scale

Build book 3B to page 12, step 12.

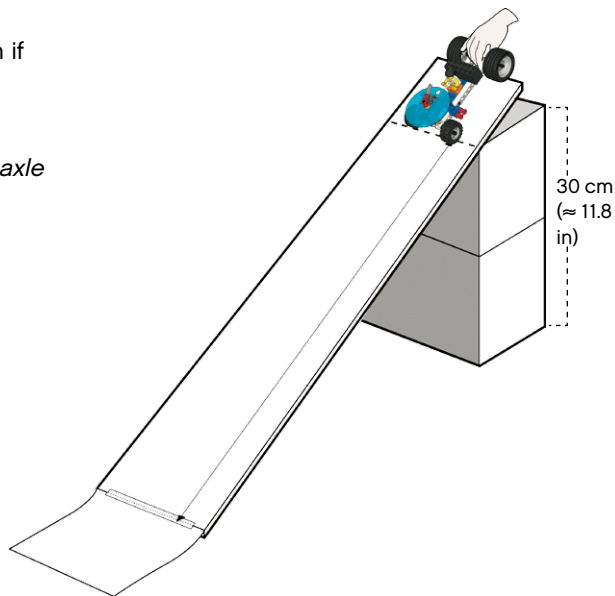
Replace the 8-tooth gear wheel with the 24 tooth gear. Predict and then test how far the cart will roll before the pointer completes one revolution.

It rolls 3 meters (\approx 3 yards). The new gear wheel has 3 times as many teeth as the small one. The worm gear has to turn 3 times as often to get the 24-tooth gear wheel to turn once. Now you will need to calibrate the scale to measure distances accurately to 3 meters (\approx 3 yards).

Super Slope

Predict first and then test what will happen if you double the height of the hill.

You double the potential energy, double the moving energy, but do not double the axle friction.



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Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
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Notes:											

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b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Freewheeling

Name(s): _____

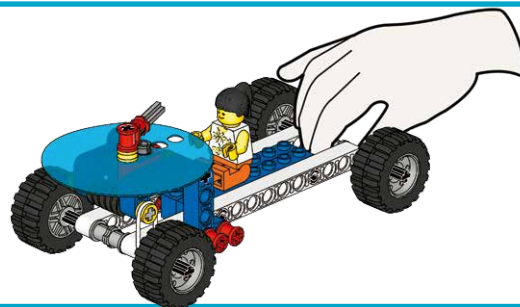
**Which will roll furthest? Heavier or lighter carts, with bigger or smaller wheels?
Let's find out!**



Build the Freewheeler

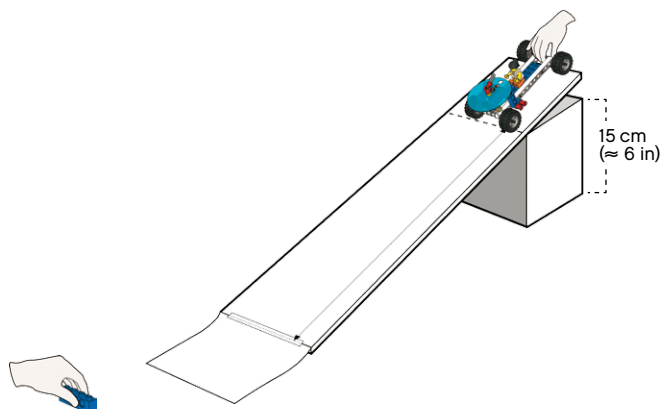
(all of book 3A and book 3B to page 6, step 12)

- Check all axles and bushings to make sure the wheels turn smoothly
- Let your freewheeler run down the ramp



Which will roll further ... heavy or light loads?

- Tip: Place a marker brick next to the track where you predict the cart will stop
- Reset the pointer on the dial after each test run



Are big wheels better than small?

- Try using big wheels on the back axle

**Test accordingly,
following the challenges below:**

	My Prediction	My Measurements
Extra weight 		
Big wheels 		
Big wheels and extra weight 		
?		

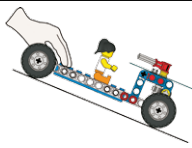
Did you know?

The empty cart weighs about 58 g (≈ 2 oz). And the weight brick weighs 53 g (≈ 1.9 oz)... almost the same!
The big wheels weigh 16 g (≈ 0.5 oz) each and the small ones only 6 g (≈ 0.2 oz) each.

Larger Scales ... and Steeper Hills

Build book 3B to page 12, step 12
Change the ramp position to be 30 cm (≈ 12in) high.
Test your different types of freewheelers.

What I found out when making the slope steeper:

	My Prediction	My Measurements
		





My amazing downhill racer!

Draw your favourite freewheeler design.
Explain how the 3 best parts work.

Freewheeling

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we tested what would change the motion of our car at the most — weight, wheel size, or steepness of the hill.				
Stability and Change: Explanations of stability and change in designed systems can be constructed by examining the forces at different scales..	<ul style="list-style-type: none"> We predicted and measured how weight would affect the distance our car traveled. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We predicted and measured how wheel size would affect the distance our car traveled. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We predicted and measured how the steepness of our hill affected distance our car traveled. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We proposed a new experiment to explore other forces that affect the distance our car travels. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we wrote a summary about what happened the motion of our car when we made the hill steeper.				
Analyzing and Interpreting Data: Identify independent and dependent variables and controls, how measurements will be recorded, and how many data are needed to support a claim.	<ul style="list-style-type: none"> We identified which was the independent and which was the dependent variable when we did the hill steepness experiment. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We identified what parts of our experiment we needed to keep constant (i.e. as 'controls') for each trial we did. We explained what we found out about the motion of our car when the hill got steeper. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver We collected data for at least three trials for every variable we tested. We used our data to support the ideas we described in our summary. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold We proposed additional experiments to help us better answer our questions and understand more about how steepness affects our car's motion. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we drew our favorite freewheeler design and explained how some parts of our car worked.				
Constructing Explanations: Apply scientific ideas or principles to design an object, tool, process or system.	<ul style="list-style-type: none"> We drew our freewheeler. We used the word 'force' in our explanation. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We used the word 'mass' or 'weight' when describing how parts of our car worked. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We used the word 'friction' when describing how parts of our car worked. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We connected at least two of these scientific terms to show how these ideas relate to each other and to our car. <input type="checkbox"/>
Notes:				



The Hammer

Technology

- Using mechanisms – levers, cams, and inclined plane
- Properties of materials
- Product safety testing
- Combining materials
- Mechanical programming of actions

Science

- Recording data
- Friction
- Force
- Momentum
- Scientific investigation

Vocabulary

- Cams
- Sequencing
- Friction
- Product safety

Other Materials Required

- Decorative materials: wool, foil, card
- Scissors
- Sticky tape

Connect

Jack and Jill are having fun hammering! They are trying to build a little shed for Zog the Dog, but the wood they are using is very hard and they need to use a lot of nails to make it hold.

After a while they are exhausted and try to think of simpler ways to hammer the nails into the wood. Two brains work better than one, they think, so together they try to solve the problem. Can you help them test a solution that will work and make the hammering much easier for them?

**How can you make a hammer machine that will efficiently hammer nails into different surfaces?
Let's find out!**



Construct

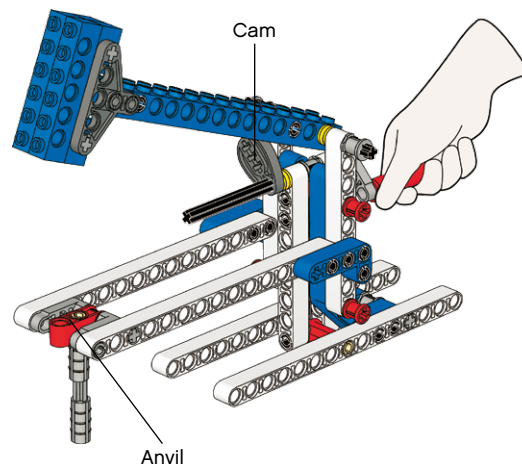
Build the Hammer

(all of book 4A and book 4B page 11, step 14)

Testing

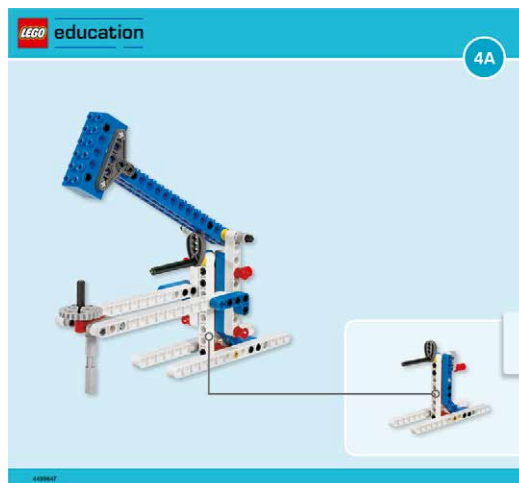
Turn the handle of the hammer by hand.
Does it rise and fall smoothly?

If it feels stiff to turn, check that the axle bushings are not rubbing on the bricks and creating too much friction.



Did you know?

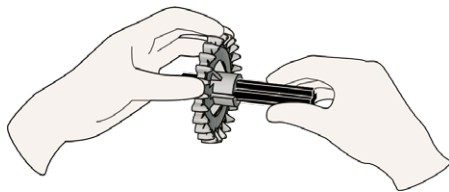
The LEGO® research labs make sure every element has exactly the right amount of grip for the job it does and for safe handling by children. We call it 'clutch power' and it is measured very carefully!



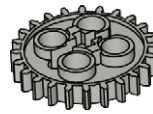
Contemplate

Can you measure grip forces by hand?

Push the axle into each gear in turn – and pull it all the way through. Can you arrange them in order from most grip (most friction) to least grip?



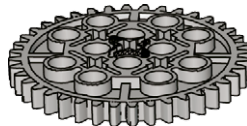
8-tooth
spur gear



24-tooth
spur gear



24-tooth
crown gear



40-tooth
spur gear

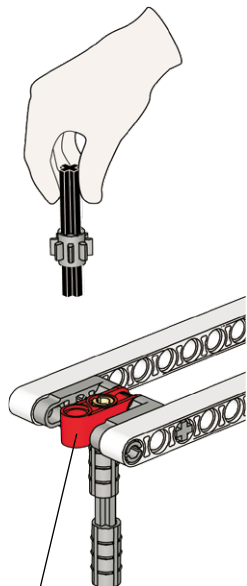


4-module axle
Black

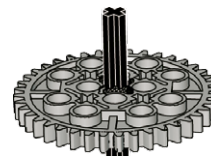
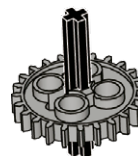
How can we measure the clutch power more accurately?

- Use the same size axle to test each gear
- Turn the handle to hammer the axle down
- Count how many hits until the axle touches the tabletop for each gear

In our tests, the 8-tooth gear has the least amount of friction. It is so small it is hard for fingers to grip. The crown gear is next. Even though it is big enough to grip, it also has pointy teeth. The 24- and 40-tooth spur gears have most friction as they have blunt teeth, are easy to grip, and transmit the most power in a model.



About 5 mm (≈ 0.2 in)
to go into the hole of
the anvil



Is the hammer a better test of axle friction than testing by feel?

If you hammer each gear several times, you will find very similar results each time. This hammer is a real scientific instrument and much better than guessing. The LEGO® labs have huge machines that do the same job, but much more accurately.

What else can the cam do?

On page 14, step 18, the modification makes it so that the hammer hits twice for each turn of the handle. Also change the axle position through the cam to make different actions and timings. Try making a slow rise and a fast drop, or a fast rise and a slow drop.

Optional: Using a heavier hammer

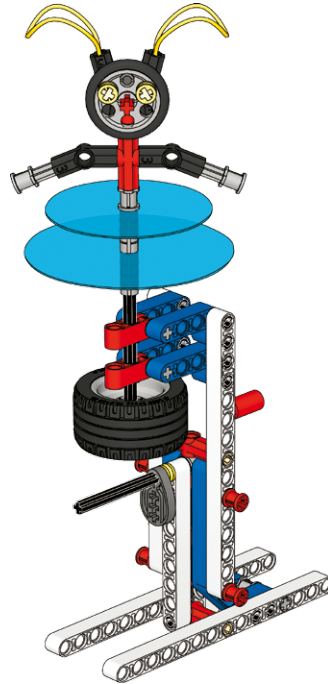
It will drive the axles through more quickly. You need to put in more energy to lift the hammer, but it drops with more force. It has more momentum. The smooth cam edge is an inclined plane, which make it easier to lift heavier weights.

Continue

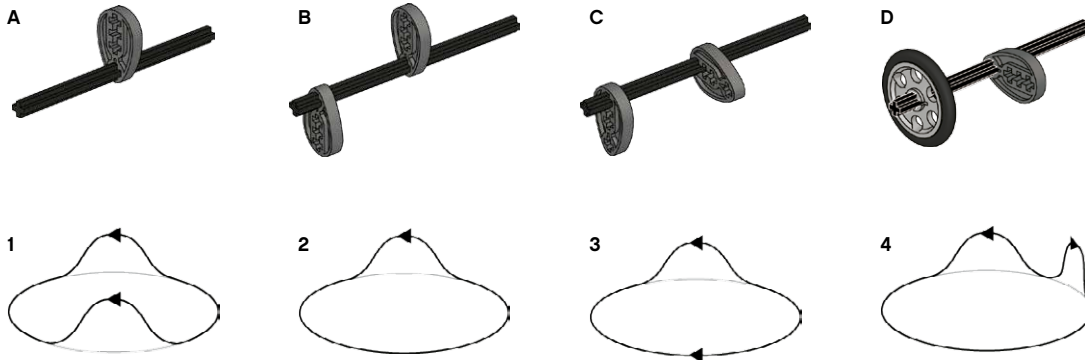
Bouncing ballerina!

- Build the ballerina in book 4B page 23, step 21
- Predict, then test what happens when you turn the handle

She rises, falls and turns at the same time.



- Can you predict the 'dancing' action made by the cam shaft arrangements shown
- Now try them and see



Answer: A2, B1, C4, D3.

Deco-rotate-her!

Add your own fun decorations. Make a card screen to hide the cams. Can anyone else work out your cam dance program just by watching her dance? Make her arms fly out as she pirouettes.



Did you know?

Cams work inside car engines, clocks, toys, sewing machines, and locks – in fact anywhere complex timed actions are required. Bring in clocks, toys, locks, and other things that contain cams. Disassemble them and see how cams move.



Note:

The wheel is in fact a round cam. It spins the dancer but does not lift her.

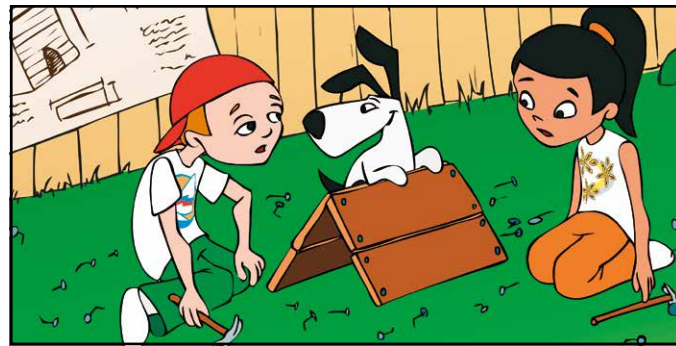
Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

The Hammer

Name(s): _____

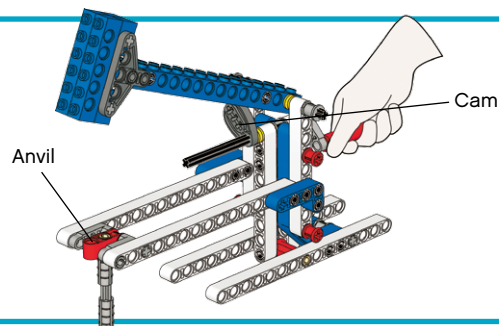
How can you make a hammer machine that makes it easy to hammer different nails into different surfaces? Let's find out!



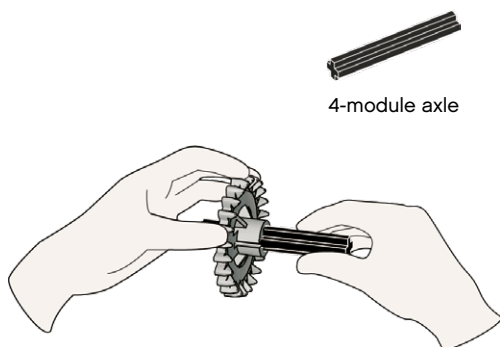
Build the Hammer

(all of book 4A and book 4B page 11, step 14)


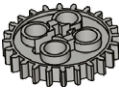

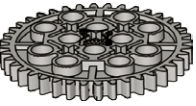
Make sure that the hammer lifts and drops smoothly. If it is too stiff, loosen the bushings and make sure all other elements fit tightly together.



Which gears have the most friction when tested by hand?

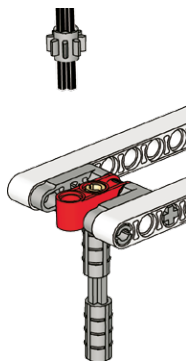


How much force is needed to push the axle through each gear?

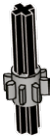



			
8-tooth spur gear	24-tooth spur gear	24-tooth crown gear	40-tooth spur gear

4 = most force, 1 = least force

Which gears have most the friction when tested by the hammer?



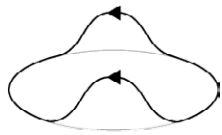
How many hits with the hammer are needed to push the axle through each gear?

			
8 tooth	24 tooth	24-tooth crown gear	40 tooth

Which is the better test system, and why?

Ballerina

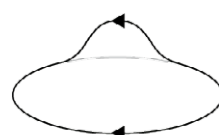
- Build the ballerina, from book 4B to page 23, step 21
- Try out these cam shaft designs (dance program)
- Connect each cam shaft with one of the 4 'dance diagrams'



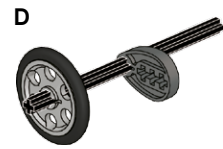
Dance diagram 1



Dance diagram 2



Dance diagram 3



Dance diagram 4



Also try:

- Amazing decorations
- Hiding your cams – can anyone guess your dance program
- Making the ballerina's arms wave
- Making your own cam profiles

My Moving Sculpture





Draw and label your favorite moving sculpture or animated toy that uses cams. Explain how the best three parts work.



The Hammer

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built an animated toy and wrote an explanation that describes what caused the patterns of motion we observed.				
Patterns: Observed patterns of forms and events prompt questions about relationships and the factors that influence them.	<ul style="list-style-type: none"> We drew and labeled the parts of the animated toy. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We identified the location of the cam(s), wheel(s), and shaft responsible for the pattern we saw. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We included a diagram showing the pattern we observed We explained how the cams and/or wheels make the pattern in the motion we observed. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We tried at least one more cam shaft design We used words and a diagram to explain how this new cam shaft design caused the pattern in the motion we observed. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we investigated which gears have the most friction when tested by hand and by the hammer.				
Analyzing and Interpreting Data: Seek to improve precision and accuracy of data with better tools and methods.	<ul style="list-style-type: none"> We completed our tests by hand and by the hammer for all four gears shown in our data table. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We picked which system is better. We explained why. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. Our explanation clearly describes which test is more accurate. We explained why. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We used the best test method on three different combinations of gears (i.e. an 8 tooth onto of a 24 tooth or 40 tooth, etc). <input type="checkbox"/>
3. Student work related to this Practice: 3. Student work related to this Practice: In this project, I explained whether the hand or hammer was best the best test for gear friction. In my explanation, I used evidence from my experiments.				
Constructing Explanations: Construct a scientific explanation based on valid and reliable evidence obtained from student's own experiments.	<ul style="list-style-type: none"> Our explanation for which test was best referred to what we discovered in our experiment. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We correctly used numbers from our experiment in to support our ideas. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained why the number of hammer hits can be used as a measurement for gear friction. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We shared our explanation and evidence with classmates. We revised our explanation to make it more clear. <input type="checkbox"/>
Notes: 				



Trundle Wheel

Technology

- Using mechanisms – gear ratios, gearing down
- Assembling components
- Combining materials

Science

- Measuring distance
- Calibrating scales
- Scientific investigations

Vocabulary

- Calibrating
- Scales
- Gearing down
- Errors
- Accuracy

Other Materials Required

- Ruler
- Three straight-edged objects less than 1 m (\approx 1 yd) long
- Space on a smooth floor to safely carry out a long jump
- Whiteboard markers

Connect

Jack and Jill are in the park preparing for the school sports day. Their favorite sport is the long jump. Jack has just made a huge jump. He is all excited and wants to know how long his jump is.

Jill has not got a ruler long enough to measure the distance so she is doing it in footsteps. Zog the Dog feels that he is much better at jumping so he is trying too.

Jill says that Jack's jump was 58 cm (\approx 22.8 in).

Jill takes her turn on the long jump. She says her jump was 4 meters (\approx 4 yards), so Jack thinks she is just guessing ... and not very well, either!

They need some sort of device that can measure a long jump properly.

**What sort of measuring machine can you invent that could measure a long jump?
Let's find out!**

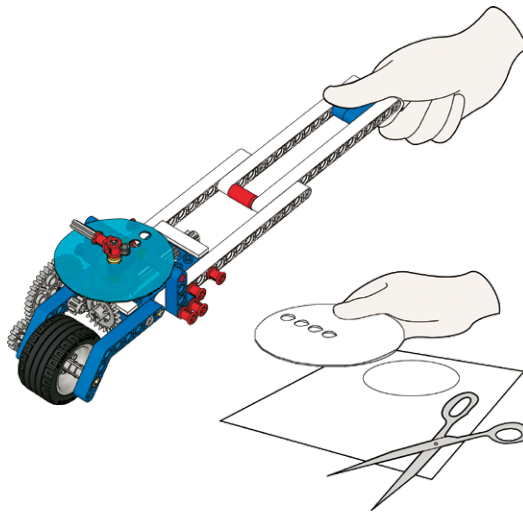


Construct

Build the Trundle Wheel

(all of book 5A and book 5B to page 6, step 11)

- If using whiteboard markers, you can write directly on the blank plastic dial disc. Otherwise trace around the disc to create your own copy
- Make sure that the pointer moves smoothly as you push the trundle wheel. If it is stiff, loosen overly tight axle bushings and make sure all other elements are firmly pressed together
- What is this measuring device good at measuring? Ask the students for ideas and draw up a list
- Measure all sort of lengths, such as your arm, hand, and leg to get a feel for measuring



Contemplate

Stepping Out: Making a Foot Wheeler

How many “feet” fit on the scale?

Measure your shoe – several times! Mark zero and then add a new mark to the dial each time you reach the end of your shoe until you’ve been around the scale (you probably won’t get a whole number of shoes).

This is calibrating the scale in units of ‘shoe’.

Predict

How many shoes wide is your desk! First use your foot wheeler to measure it! Then take off your shoe and measure it with your shoe. How accurate was your foot wheeler?

What are the problems of measuring in shoe lengths?

*People’s feet are not always the same size!
This is why we usually select a standard unit of measurements, such as the metric system or US customary system.*

Meter magic trundle: is it better than a ruler?

Collect three items that you believe are less than

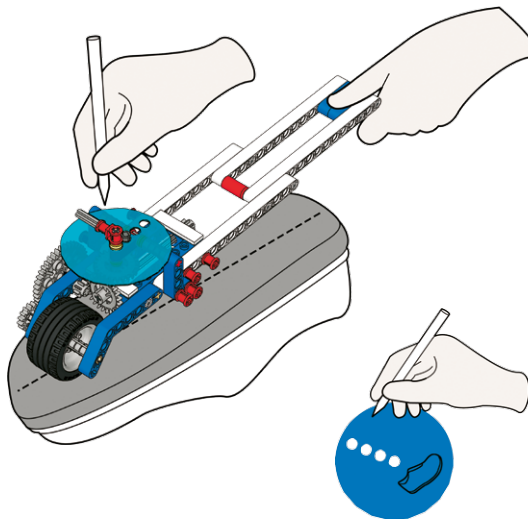
1 meter (≈ 1 yard) long.

- Predict how long each is
- Measure with the trundle wheel
- Measure with a ruler
- What did you discover?

Rulers are the most accurate, usually followed closely by the trundle wheel, and then predictions. What trundle wheels are really good at is quickly measuring things that are longer than a normal ruler.

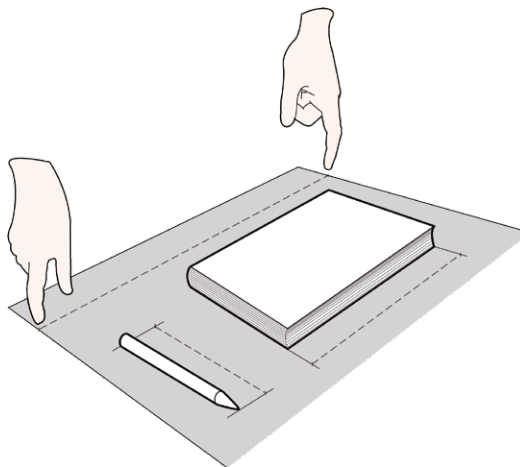
But what happens for distances over 1 m (≈ 1 yd)?
What happens with your perfect long jump?

If you measure 1.5 m (≈ 1.5 yd), the pointer shows 50 cm (≈ 19.6 in)! The pointer has been around once and is starting again. This may be a problem: you need to remember how many times the pointer passes the zero marker.



Note:
Learn how to reset the pointer after each measurement

Note:
The accuracy of our scale depends on how much pressure the children place on the tire. Light pressure is ideal. Try it and see.



Continue

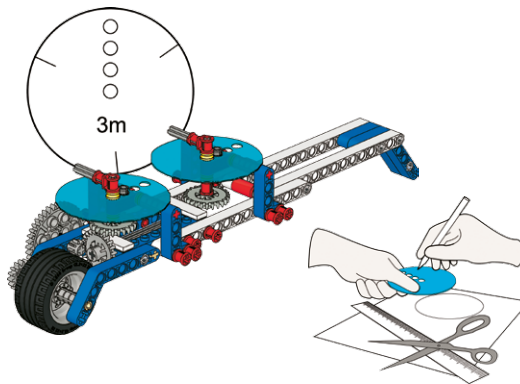
How can we use the trundle wheel to measure long jumps of more than 1 m (≈ 1 yd)?

What might happen if we add another dial with a pointer that moves much slower than the first dial?

It should measure more than 1 meter (≈ 1 yard).

Build the model to page 12, step 11.

Trace and cut out the 3 m (≈ 3 yds) dial in paper if you want to keep your dials. Wheel it further than 1 m (≈ 1 yd). Practice reading both scales for extra accuracy.



Now it's time to start jumping!

- Students should practice their long jump skills, though obviously conditions in the classroom have to be taken into consideration and safety comes first. One possibility is to go outside and practice jumps on a lawn, another is to use a standing long jump
- Predict how far you'll jump. Then use the trundle wheel to measure the result. You could also try measuring with a ruler. What did you discover?



It is much easier to use the trundle wheel. It measures up to 3 m (≈ 3 yds) in one go. But you must read two dials for the most accuracy. By comparison, you need to move the ruler a lot and add up the amounts in your head. And every time you move the ruler there's a chance that an error might occur.

Leonardo's Magic Body Facts

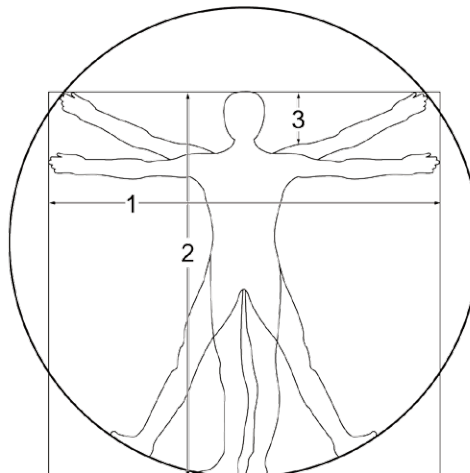
What does Leonardo da Vinci's famous symbol mean?

Try measuring all the distances shown.

See if you can spot any 'patterns'.

If another person tells you her height, can you tell how long her arm span will be – or how long her head will be?

Often arm span (1) and height (2) are the same. The head (3) is often 1/6th of a person's full height. These are handy rules to know when drawing people. What about legs and arms?



Gear Facts

The two pointers are connected via an 8-tooth and a 24-tooth gear. This gears down the speed of the second pointer three times, allowing one dial to now cover 3 m (≈ 3 yds).

Idea:

The wonderful thing about a trundle as opposed to a ruler is also that it is great at measuring around curves. Estimate your head and waist size – then measure and be amazed.

Note:

You may need to measure with the person standing against a wall and running the trundle wheel up the wall beside them.

Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Trundle Wheel

Name(s): _____

What sort of machine can you invent that could measure a long jump?
Let's find out!



Build the Trundle Wheel

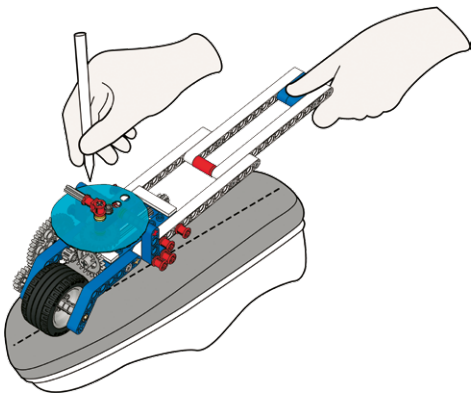
(all of book 5A and book 5B to page 6, step 11)

How many shoes wide is your desk?

My answer: _____

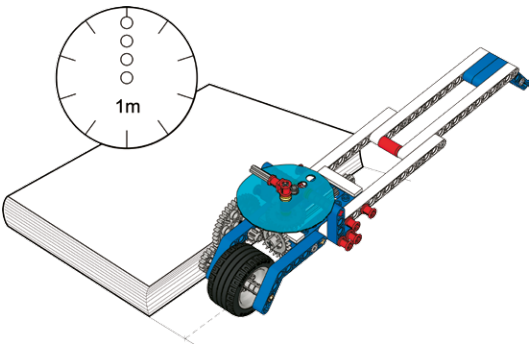
How many shoe lengths will fit on your dial?

My answer: _____



Measuring Objects

- Collect three more objects shorter than 1 m (≈ 1 yd)
- Estimate the length of each
- Measure with the trundle wheel
- Measure with a ruler



	My Estimate	My Trundle Reading	My Ruler Reading
Pen	cm (\approx in)	cm (\approx in)	cm (\approx in)
Pencil Case	cm (\approx in)	cm (\approx in)	cm (\approx in)
	cm (\approx in)	cm (\approx in)	cm (\approx in)
	cm (\approx in)	cm (\approx in)	cm (\approx in)
	cm (\approx in)	cm (\approx in)	cm (\approx in)

Doing the long jump!

- Build your model to page 12, step 11
- Add the 3 m (≈ 3 yds) dial to the trundle wheel
- Predict and then measure your long jump
- Do this three times



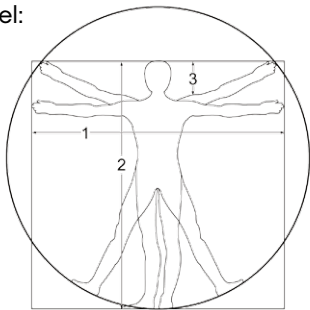
	My Prediction	My Measurements
Jump 1	cm (≈ in)	cm (≈ in)
Jump 2	cm (≈ in)	cm (≈ in)
Jump 3	cm (≈ in)	cm (≈ in)

In what ways is a trundle wheel better than a ruler?

My answer: _____

Leonardo's Magic Body Facts

Leonardo's Wheel:



	My Estimate	My Trundle Reading
Arm Span (1)	cm (≈ in)	cm (≈ in)
Height (2)	cm (≈ in)	cm (≈ in)
Head (3)	cm (≈ in)	cm (≈ in)





My Amazing Trundle Machine!

Draw and label your creative design for measuring distances.
Explain how the three best parts of your amazing machine work.

Trundle Wheel

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a trundle wheel and explained how it worked.				
Scale, Proportion, and Quantity: Use proportional relationships to gather information about the magnitude of properties.	<ul style="list-style-type: none"> We explained how the wheel turning causes the disk to turn. We explained how the markings on the disk tell us the measurement in 'cm'. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We related the number of markings on our disk to the number of centimeters we measured. We described how one trundle wheel can be used to measure > 1m. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained when we needed to add a second disk to the trundle wheel design. We described the ratio of complete turns the first disk made to the turns of the second disk. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We explained why the ratio of the gears in our trundle wheel is important to making it work. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we built a trundle wheel measurement machine and used it to collect data for small and large measurements.				
Analyzing and Interpreting Data: Consider measurement error and seek to improve precision and accuracy of data with better tools.	<ul style="list-style-type: none"> We built a working trundle wheel measurement machine. We completed measuring different objects. We made a measurement disk to record lengths in 'cm' for the first disk. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We completed the long jump measurements. We compared our trundle wheel measurements with the ones made by a ruler. We made measurement disks to record lengths in 'cm' and 'm'. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We repeated measurements to improve our results if the ruler and trundle wheel measurements were very different. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We completed more measurements than we were asked to do on our Student Worksheet. We compared our measurements with our classmates. We worked together with classmates to improve our measurements. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we explained why our trundle wheel measurement machine is, in some ways, better than a ruler.				
Constructing Explanations: Construct a scientific explanation based on valid and reliable evidence from student's own experiments.	<ul style="list-style-type: none"> We explained one way that our trundle wheel was better than a ruler. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We used an example from our own experiment to support our explanation. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained more than one way that our trundle wheel was better than a ruler. We used multiple examples from our own experiments to support our explanations. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We added at least one way in which the ruler is better than our trundle wheel. <input type="checkbox"/>
Notes: 				



Letter Balance

Technology

- Using mechanisms – levers and gears
- Combining materials and components
- Testing before making improvements

Science

- Measuring weight
- Calibrating scales
- Scientific investigation

Vocabulary

- Efficiency
- Balance
- Accuracy
- Calibrate
- Scale
- Resetting
- Net weight

Other Materials Required

- Whiteboard markers for tracing the scale
- Scissors, markers or pencils, old envelopes, paper and sticky tape to make some letters and stamps
- A collection of small objects less than 150 g to weigh
- A small bag of identical coins
- Light plastic cup
- Measuring jug
- Water

Connect

Jack and Jill have set up a post office and delivery service at their school. They have a plan to write letters and send them to all their friends at school.

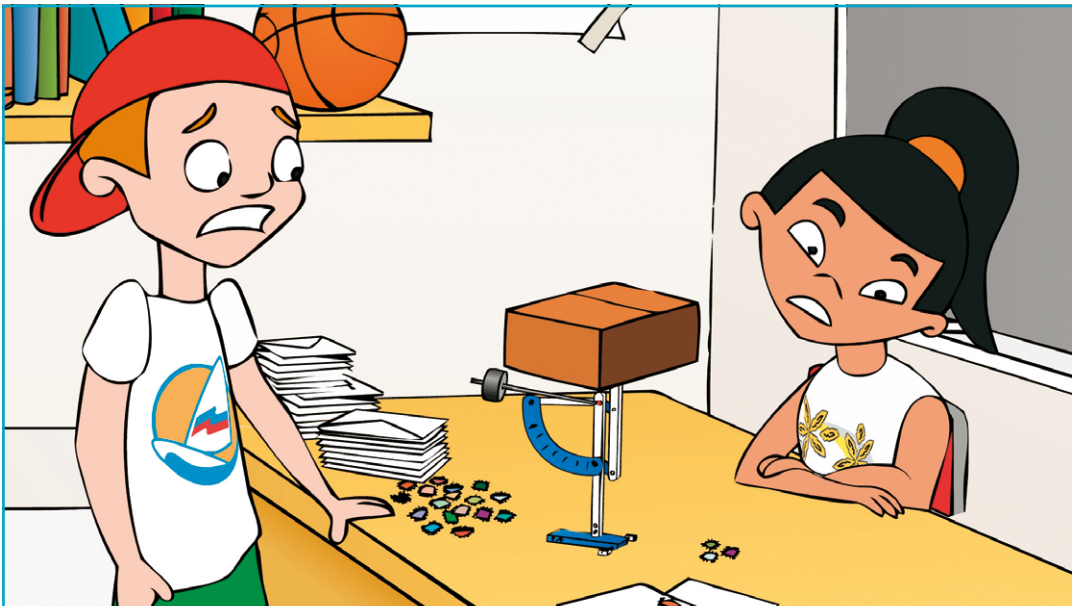
To make everything as real as possible, Jill has designed some very spectacular stamps and she is having fun weighing all the letters and finding out what stamps to put on.

Jack is also thinking of using the new post office to send a big parcel to Granny – it is her birthday soon. He wraps it up and wants to find out about stamps for the parcel but... it looks like the letter weight can't deal with such a heavy object.

How will Jack and Jill solve this problem so they can be sure what stamps to put on for Granny's birthday present to be sent off?

How can Jill work out a fair system that differentiates between the weight of the different letters and parcels her classmates are bringing to her?

Let's find out!



Construct

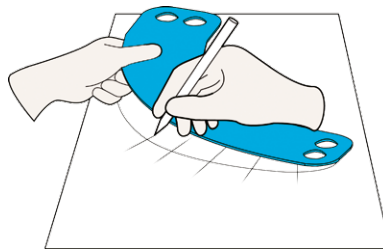
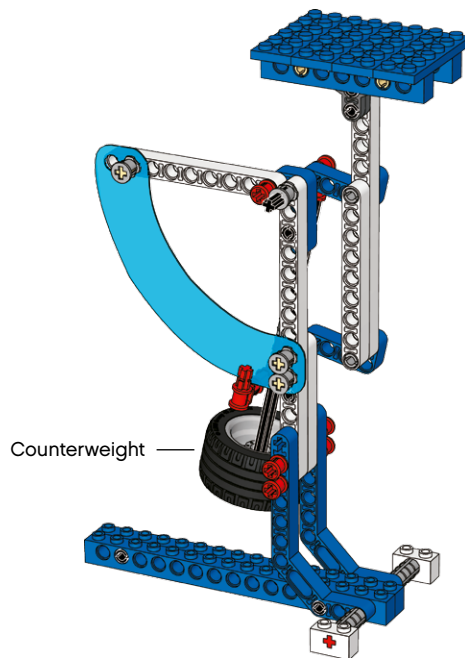
Build the Letter Balance

(all of book 6A and book 6B to page 11, step 20)

Fine-Tuning the Balance

The arm should swing freely and should return to the same spot each time. If it 'sticks' make sure the axle bushings are not too tight. Slide the counterweight up or down the axle so the pointer stops at zero on the scale.

Mark on the blue plastic disc with a white board marker or trace around it and cut out a paper copy. Put on scale markings and attach it on top of the blue plastic disc.



Tip:

To be accurate, letter balances require careful adjustment. Make sure your LEGO® letter balance is always correctly adjusted.

Did you know?

Although it is a rather complicated one, the letter balance is in fact a first-class lever.

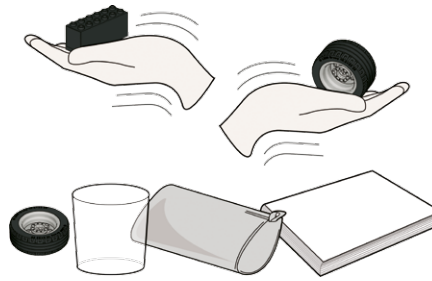
The letter becomes the effort trying to lift the load of the counterweight. Can you locate the main fulcrum or pivot point?



Contemplate

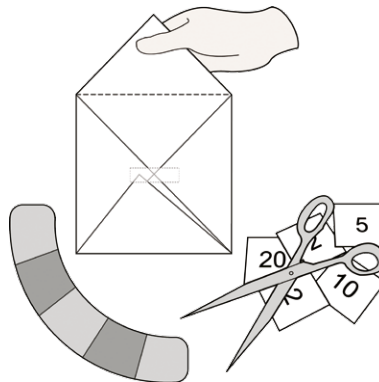
Hand versus Machine

Line up a collection of 5 objects in the order you think is from lightest to heaviest. Include the big wheel with tyre (16 g) and the weight brick (53 g). Record your estimated weights. Then weigh them. How close were your estimates? Did you get them in the right order?



School Post Office

A daily or weekly postal service in school run by children is a wonderful activity, so give it a try! Make your own envelopes, letters and packages. Design your own stamps and start weighing.

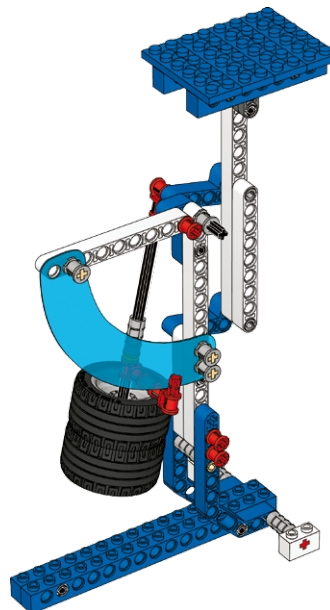


Heavyweights

How can we weigh packages over 150 g?
Ask the class for ideas, and make a list.

Build model to page 11, step 21 by adding a second wheel to the counterweight axle. Now you will need to calibrate another new blank scale or redo the blue plastic scale.

Find heavier things to weigh.
Can you find 2 different things/items that weigh approximately the same?



Tip:
Usually we are better at estimating heavier weights. The machine is nearly always more accurate than us.

Tip:
Slide the counterweight high up the axle. You may need to move the pointer too. This will make lighter objects such as letters move the arm to a greater extent across the scale. BUT you will need to calibrate a new blank scale in euro cents ... pence ... or 'stamps'.

Continue

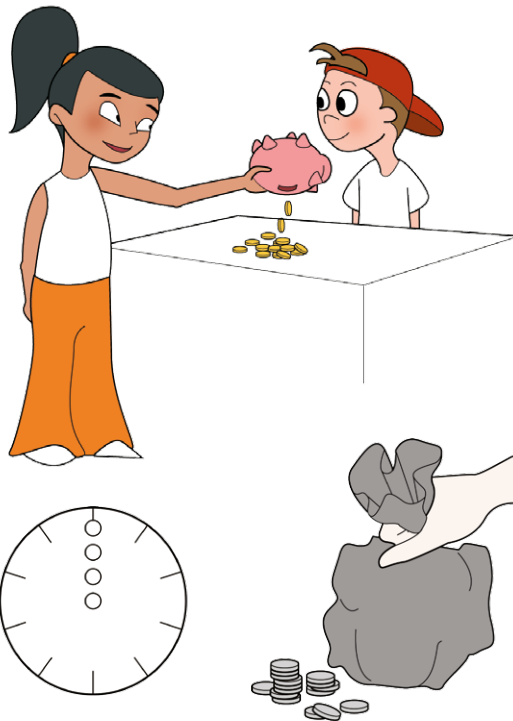
Money Bags

Let's find out: Is there a quick way to count lots of the same coins?

Build the final model with the rotating pointer page 16, step 12.

Start with a blank scale. Weigh 5, 10, and then 20 of the coins marking their positions on the scale. Work out the rest of the scale in dollars, etc.

Now test it with a 'bag of money' or just a small pile!



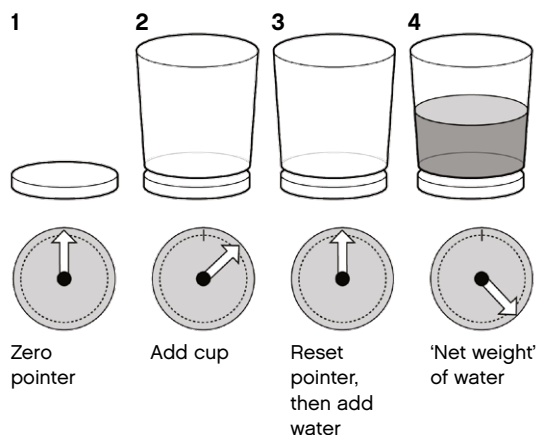
Smart Balance

Let's find out: What if we want to weigh how much fluid there is in a cup or the weight of chocolates in a box ... or coins in a piggy bank – but not their containers?

Ask for suggestions to see if the children can develop the idea of moving the pointer back to zero.

We have to subtract the weight of the container first.

1. Trace or cut out a copy of the calibrated circular scale and attach it to the model scale and reset the pointer.
2. Place a plastic cup on the balance tray.
3. Move the pointer back to zero.
Measure 100 ml of water in a measuring jug.
4. Add it to the cup ... it should weigh 100 g!
Resetting the pointer means that the weight of the container is subtracted. This way we measure the net weight (the weight of the contents only).



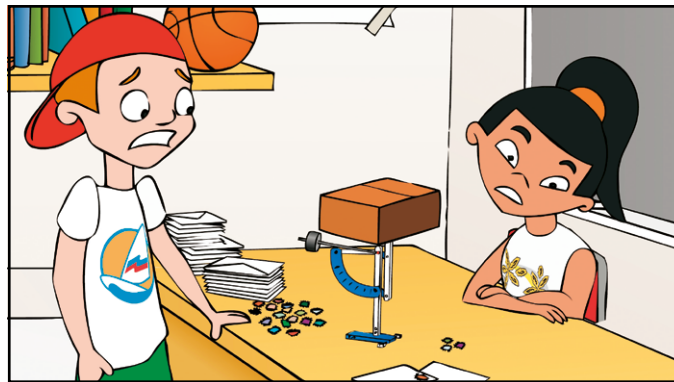
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a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
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a	to explore its limitations.										
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d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
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Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
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Notes:											

Letter Balance

Name(s): _____

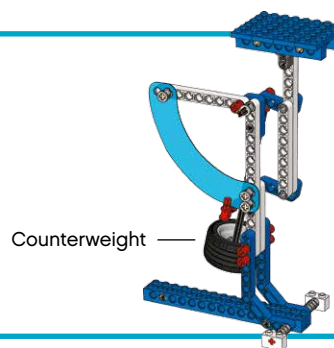
How can Jill work out a fair system that differentiates between the weight of the different letters her classmates are bringing to her?
Let's find out!



Build the Letter Balance

(all of book 6A and book 6B to page 11, step 20)

- The arm should swing freely. If not, loosen axle bushings and make sure other parts are pressed firmly together
- Slide the counterweight along its axle to reset the pointer

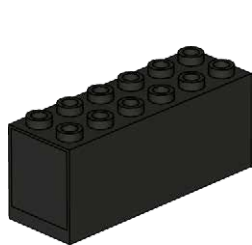
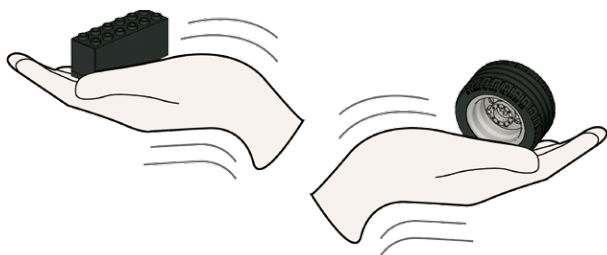


Hand versus machine: which is best?

- Line up 5 objects from lightest to heaviest
- Write them down in the table
- Estimate their weights first
- Then weigh them all

Idea:

When you are estimating, try holding one of these known weights in your other hand!



53 g



16 g

	My Objects	My Estimate	My Measurement
1		g	g
2		g	g
3		g	g
4		g	g
5		g	g

Tip:

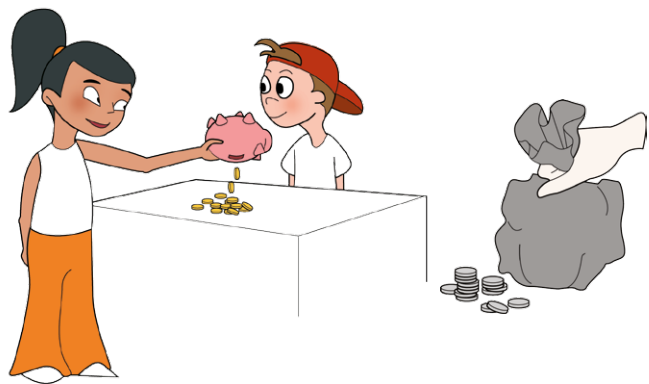
Usually we are better at estimating heavier weights. The machine is nearly always more accurate than us.

Tip:

Slide the counterweight high up the axle. You may need to move the pointer, too. This will make lighter objects such as letters move the arm to a greater extent across the scale, but you will need to calibrate a new blank scale in cents or 'stamps'.

Money Bags

- Build book 6B to page 16, step 12 with a blank scale.
- Weigh 5, 10 and 20 of the same sort of coins
 - Mark your scale in 'money'
 - Guess and then weigh with the scale how much money is in a secret 'money bag'
 - Count out the coins – how close were you?



My Guess	My Measure	My Count





My Awesome Weighing Machine

Draw and label your design for a weighing machine.
Explain how the best 3 bits work.

Letter Balance

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we drew and explained how the three important parts of our weighing machine worked.				
Cause and Effect: Mechanism and Explanation: Use cause and effect relationships to explain observations in designed systems.	<ul style="list-style-type: none"> We drew our weighing machine. We labeled the three important parts of the weighing machine. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We correctly identified the parts in our weighing machine that caused it to move the pointer for our measurements. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained which parts of our weighing machine need to be adjusted to measure heavier objects. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We explained which parts of our weighing machine did not cause it to weigh objects accurately. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we built a model of a tool to measure the weight of different objects.				
Developing and Using Models: Evaluate limitations of a model for a proposed object or tool.	<ul style="list-style-type: none"> We built the weighing machine according to the building instructions. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We put markings on our blue plastic scale so we could measure objects in grams. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We built our weighing machine to handle heavier objects by adding an additional counterweight wheel. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We compared our scale with the scales created by our classmates. We used our observations to revise our weighing machine and make improvements. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we investigated which was better at measuring weight, our hand or our weighing machine.				
Planning and Carrying Out Investigations: Evaluate the accuracy of various methods for collecting data.	<ul style="list-style-type: none"> We estimated the weight of at least three objects with our hands. We weighed at least three objects with our weighing machine. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We estimated the weight of two more objects with our hands. We weighed two more objects with our weighing machine. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We changed our weighing machine and investigated the weight of different numbers of coins. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We correctly guessed (within a few coins) the number of coins in the secret money bag. We weighed and made predictions for at least two additional secret money bags. <input type="checkbox"/>
Notes:				



Click-Clock

Technology

- Combining materials and components
- Using mechanisms – gears
- Testing before making improvements

Science

- Measuring time
- Calibrating scales
- Investigating momentum
- Energy
- Scientific investigation

Vocabulary

- Pendulum
- Accuracy
- Calibrate
- Scale
- Energy

Other Materials Required

- Stopwatch or timer

Connect

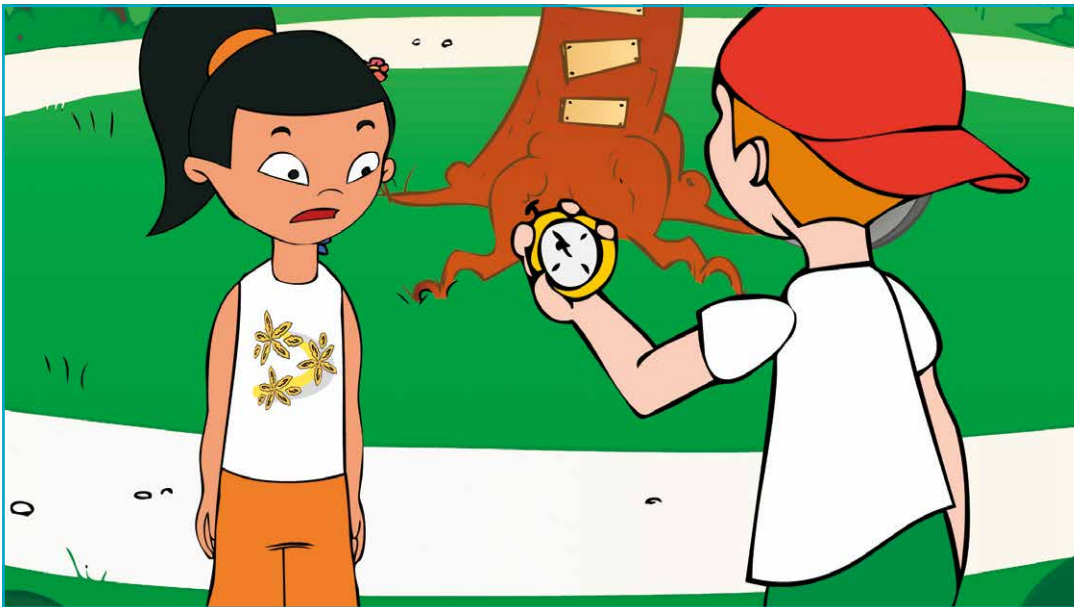
Jack and Jill have been watching the Olympics on the TV and have become quite keen on finding out what it takes to beat Olympic records. They go out in the garden and decide to race 3 times around the old oak tree on the lawn.

Jill is the first to go and Jack says: 'Ready, Set, Go!' He presses the stopwatch in his hand at the exact time of saying "Go"! Unfortunately, in his excitement, Jack presses too hard and the stopwatch breaks.

How are they now going to time the race around the oak tree?

How can we make a timer that can help us time races?

Let's find out!



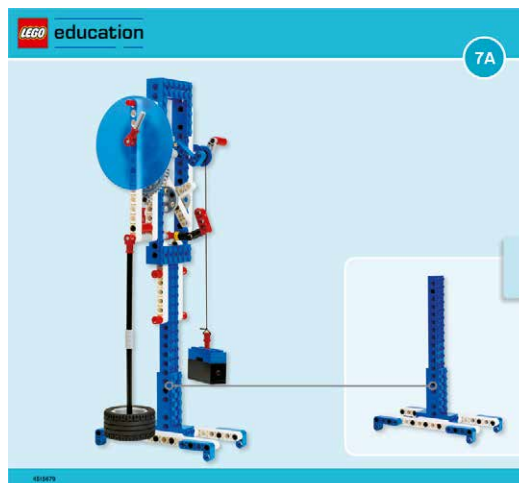
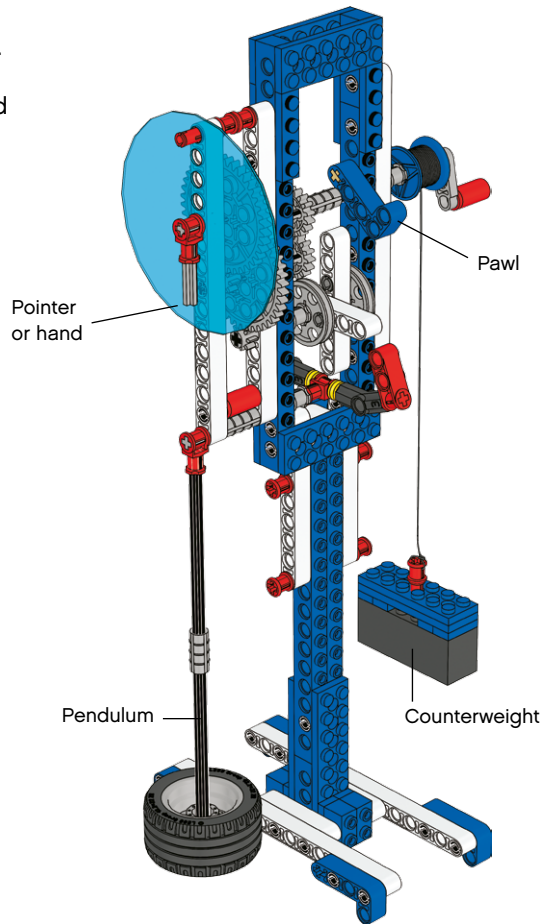
Construct

Build the Click-Clock

(All of book 7A and book 7B to page 17, step 26).

Release the pawl stopping the top axle, extend the gear wheels and use the handle to wind up the counterweight. Reposition the gear wheels, reset the pawl and start the pendulum swinging.

What happens?
The click-clock starts to tick.



Contemplate

Making time go slower or faster!

First predict, then test.

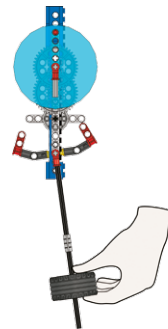
- A. Make sure the big wheel is at it's lowest position. How many seconds does it take for the pointer to go around the dial once?

It takes approximately 70 seconds.



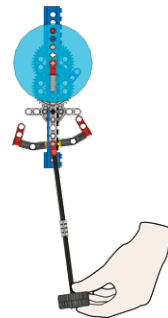
- B. Slide the big wheel high up on the axle, set the pendulum swinging, and try timing it again.

The clock ticks even faster. The pointer rotates in approximately 55 seconds.



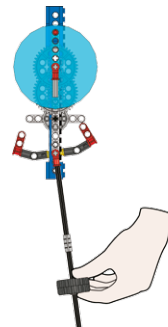
- C. Change the pendulum to a small wheel as shown on page 18, step 27. How many seconds does it now take for the pointer to go around the dial once?

*It takes approximately 56 seconds.
It is faster than the same position with a big wheel because a small wheel weighs less and needs less energy to make the pendulum move back and forth.*



Calibrating to 1 Minute

It is possible to calibrate to almost 1 minute. Move the small wheel up and down the pendulum until you find a position where the pointer goes around the dial in approximately 60 seconds.



Tip:

You can get close to 1 minute by positioning the wheel approximately 3 cm (approximately 1.18 in.) up the pendulum.

Continue

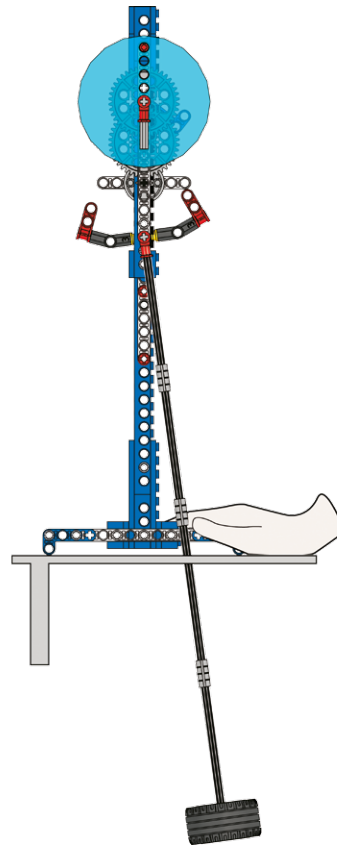
Long Pendulum

Build book 7B to page 20, step 3.

How about finding out what happens when the pendulum is made much longer?

Place the click-clock at the edge of a table.
Hold the base to keep it steady.
What happens?

*The click-clock runs much slower.
The pendulum swings more slowly which means that you can now time much more than a minute because a longer and heavier pendulum needs more energy and takes more time to swing back and forth.*



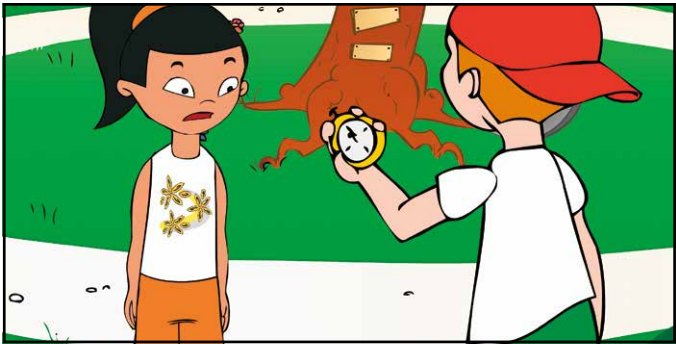
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c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Click-Clock

Name(s): _____

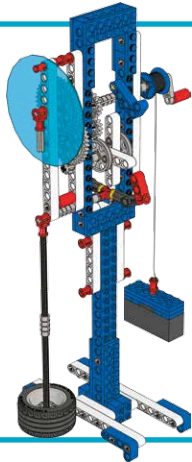
How can we make a timer that can help us time races?
Let's find out!



Build the Click-Clock

(all of book 7A and book 7B to page 17, step 26)




Wind it up and start it ticking by swinging the pendulum.



Making time go slower or faster!

Predict first, then test following the challenges in the table.

How many seconds does it take for the pointer to go around the dial once in models A, B and C?

	My Prediction	My Measurements
A 	seconds	seconds
B 	seconds	seconds
C 	seconds	seconds

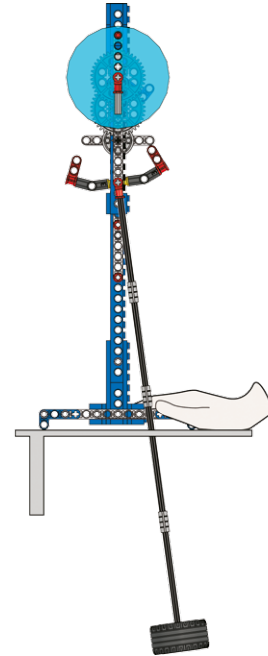
Tip:
You can get close to one minute by positioning the wheel approximately 3 cm up the pendulum.

Long Pendulum

Build book 7B to page 20, step 3.

Place the click-clock at the edge of a table.
Hold the base to keep it steady.
What happens?

My answer:







My Shock-O'clock:

Draw your best design for a timer and possibly an idea about how to trigger a funny sound after one minute. Explain how the 3 best bits of your shock o'clock work.

Click-Clock

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built the long pendulum and described its motion compared to the smaller pendulums from the first part of the activity.				
Scale, Proportion, and Quantity: It is important to recognize how changes in scale, proportion, and quantity affect a system's structure and performance.	<ul style="list-style-type: none"> We built the long pendulum. We described what we observed. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We compared our observations of the long pendulum with our observations of the smaller pendulums. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We measured the number of seconds it took for the pointer to go around. We calculated ratios to compare the times of the long pendulum vs. the shorter pendulums. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We compared the ratio of the pendulums lengths to the ratio of the pendulums times. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we built a click-clock timer and made changes to the pendulum to see if we could make the click-clock go slower or faster.				
Planning and Carrying Out Investigations: Collect data about the performance of a proposed object under a range of conditions.	<ul style="list-style-type: none"> We completed the construction of our click-clock timer. We changed the position and type of wheel on the pendulum. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We wrote down at least three predictions and measurements for different wheel positions and types. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We used the provided tip to make the click-clock time one minute. We wrote down our measurements that were close to one minute. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We proposed additional experiments to our teacher using the click-clock timer. We wrote down our measurements for at least one of those experiments. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we labeled our favorite shock-o'clock timer design. We described how three important parts of our shock-o'clock worked.				
Obtaining, Evaluating, and Communicating Information: Integrate qualitative and/or quantitative information in written text with visual displays to clarify claims and findings.	<ul style="list-style-type: none"> We labeled one important part of our shock-o'clock design. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We labeled two more important parts of our shock-o'clock design. We explained how one of important parts of our shock-o'clock works. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained how all three important parts of our shock-o'clock work. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We created and shared our diagram and explanation to classmates. We revised our work and made it more clear for our classmates to understand. <input type="checkbox"/>
Notes:				



Windmill

Technology

- Using mechanisms – gearing up and down
- Designing and making
- Combining materials
- Ratchets
- Safety and control systems

Science

- Forces and motion
- Renewable energy
- Measuring weight
- Measuring time
- Force
- Area
- Fair testing
- Energy capture, storage and use
- Scientific investigations

Vocabulary

- Renewable energy
- Force
- Area
- Weight
- Angle
- Shape
- Gearing down
- Efficiency

Other Materials Required

- Wind or desk fan
- Brass weights or play dough
- Stopwatch or other form of timer with a second hand
- Optional: card and scissors to make own sails for the windmill

Connect

Jack and Jill have found a huge but heavy treasure chest buried near an old mine. It is really heavy and though they try as hard as they can, they can't pull it out of the hole.

The old windmill nearby once used to lift water out of the mine and they are wondering if it can be of any help to them.

Zog the Dog has done a very good job helping them to dig out the treasure chest so he is pretty tired too. He walks away from Jack and Jill to rest a bit and suddenly finds a long piece of rope. He runs back to the two kids to suggest that they take him for a walk on his new "leash".

Jack has once seen a film where a mill was used to lift up something and seeing the rope he immediately tells Jill about his idea. Now they know they can figure out how to get the treasure out of the hole!

**How can you use a windmill and a rope to lift a heavy load?
Let's find out!**



Construct

Warning!

Fans are potentially dangerous. Make sure that children handle them with great care!

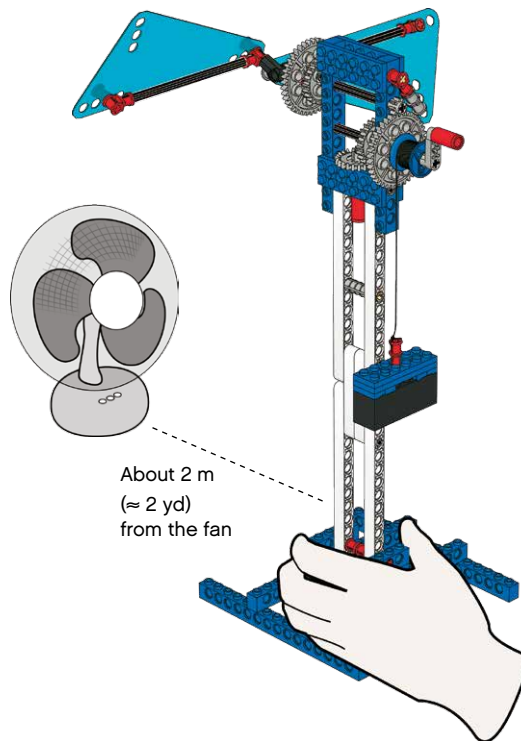
Build the Windmill

(all of book 8A and book 8B to page 12, step 17)

- Spin the mill by hand. Is it running smoothly?
- If it feels stiff to turn, loosen the axle bushings and make sure all other elements fit tightly together

Setting up the Windmill

- Position the fan on the floor near a power outlet
- Place the model about 2 m (\approx 2 yd) away
- Choose a power setting, and move the model back and forth to find a distance where the wind speed is just enough to lift the weight brick, slowly
- KEEP THIS POWER SETTING FOR ALL TESTS (until you want to test the effects of different wind speeds, of course)
- Make a long line (e.g. with tape) in front of the windmill. This is the test zone (where it is safe), and behind the line several groups can test several mills at the same time. Check that all the windmills are getting the same amount of wind



Contemplate

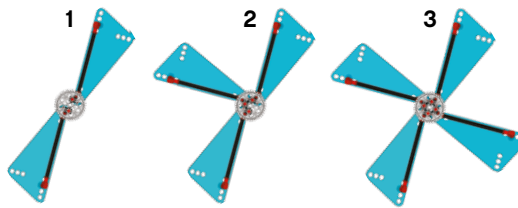
What is the best number of sails to use?

Predict and test which combination will lift up the treasure chest (weight brick) most quickly. Can you explain why?

Example 3 is best. It has the most area in which to catch the wind energy.

Surprise!

Example 2 with the sails off-center is usually the worst. It is too unbalanced to work efficiently even though it has more area than Example 1 with just two sails.



Idea:

Does shape matter? If you have time, try making sails of different shaped pieces of card, but with the same area as that used in your models.

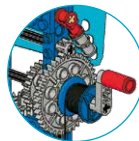
Note:

Each sail has an area of approx. 40 cm (≈ 15.7 in)².

What does the ratchet do when:

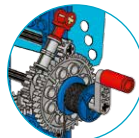
- The load is being lifted up and the wind stops?

The mill stops but the ratchet stops the heavy load from falling — a good safety feature.



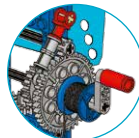
- The wind is blowing and you flip the ratchet to this position?

The mill stalls. The forces are opposite.



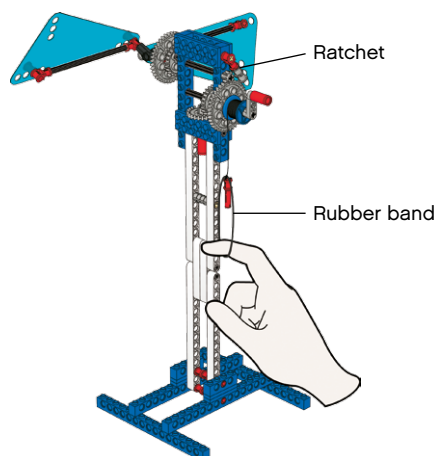
- The load is up, the wind stops, and you flip the ratchet to this position?

It will become a fan powered by the energy stored in the falling load. You get the wind back again!



Rubber Band Force Meter

Tie a rubber band to the lifting string or use a spring balance to measure the lifting force before the mill stalls. Measure how much it stretches. You'll be amazed by the power generated!



Continue

In a spin!

How can we store and use energy later?

In this exercise we are actually cranking the weight up by hand. You can do it using wind power too, of course, if you then take off the sails before releasing the top.

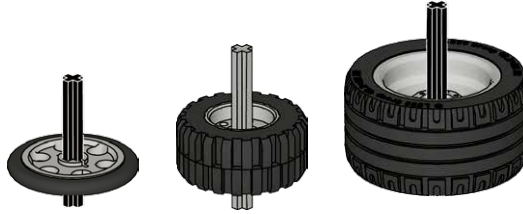
Disconnect the gearbox as in page 14, step 1 and make the three different spinning tops page 14, step 16.

- Crank up the weight (adding energy) and flip the ratchet to hold the weight up (store the energy)
- Connect a spinning top
- Position the weight so it will fall over the edge of a table
- Flip the ratchet to release the energy in the weight brick so it spins the top
- Lift to release the spinning top
- This takes skill so be patient
- Which top will spin the longest and why? Predict and test more times with each spinner

More Spins

Invent your own spinners to see if you can get even more speed and longer spinning times.

Invent your own spinning games and introduce your very own scoring system.



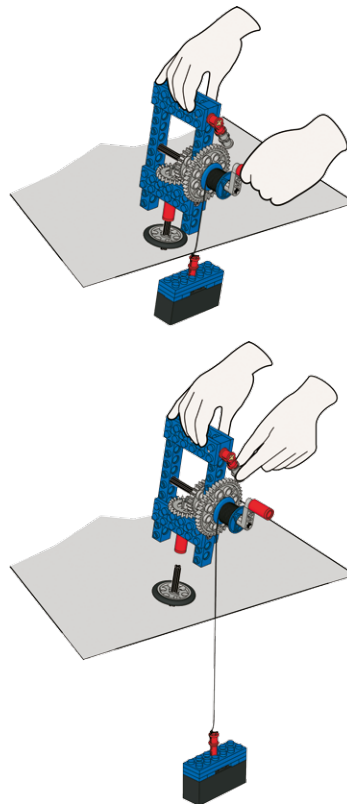
Did you know?

The different spinning tops weigh approx.:

2 g (≈ 0.1 oz)

8 g (≈ 0.28 oz)

16 g (≈ 0.5 oz)



Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
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b	that are based on scientific ideas, laws, and theories.										
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d	that apply scientific ideas, laws, and theories.										
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Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
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a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Windmill

Name(s): _____

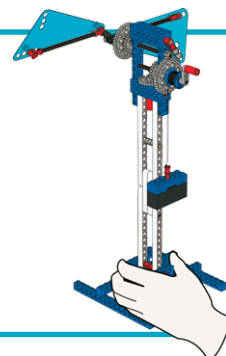
How can you use a windmill and a rope to lift a heavy load?
Let's find out!



Build the Windmill

(all of book 8A and book 8B to page 12, step 17)

- Make sure it turns smoothly
- If it feels stiff to turn, loosen the axle bushings and make sure all other elements fit tightly together





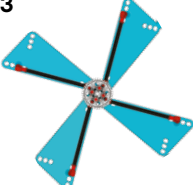
What difference does the number of sails make?

- Predict and test how fast each design will lift the treasure chest (weight brick). Use some sort of timing device
- Use the same wind speed each time

Slow

Fast

Medium

1	2	3
		
My Prediction	My Prediction	My prediction
Actual Speed	Actual Speed	Actual Speed

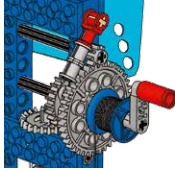
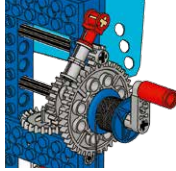
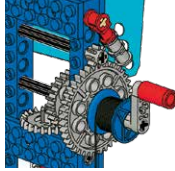
What difference does the ratchet make?

Predict and test what will happen to the treasure chest with each position of the ratchet with or without wind.

Lift

Stopped

Fall

1: Wind	2: No wind	3: No wind
		
My Prediction	My Prediction	My Prediction
What happened?	What happened?	What happened?

In a Spin

Build the wind-up top model page 14, step 1 and the three different spinning tops on pages 14, 15 and 16.

- Use the energy from a falling weight brick to power these spinning tops
- How long will each top spin for?



Also try:

- Colored spirals on card spinners
- Gears as spinners
- Inventing your own spinning game and making a scoring system

My Prediction	My Prediction	My Prediction
Actual Spin Time	Actual Spin Time	Actual Spin Time





My Magnificent Mill

Draw and label your design for capturing and using wind energy. Explain how the three best parts work.

Windmill

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a windmill to lift a treasure chest and a mechanism to power a spinning top.				
Energy and Matter: Flows, Cycles, and Conservation: Energy may take different forms and can be tracked as energy flows through a design system.	<ul style="list-style-type: none"> We built a windmill to lift a treasure chest. We built windmill blades with different numbers of sails. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We built and tested a ratchet mechanism. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We used the gearbox from the windmill to power a spinning top. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We invented and tested new spinners or a spinning game. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we picked different variables to test so we could investigate what affected the motion of our windmill, the treasure chest, and our spinning tops.				
Planning and Carrying out Investigations: Plan an investigation and in the investigation identify independent and dependent variables and controls	<ul style="list-style-type: none"> We completed at least two out of the three possible investigations on our student worksheet. We identified at least one 'control' (e.g. sails, ratchets or spinning tops) and to keep the same through our experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We completed all three investigations. We chose the correct measurement tools. We identified at least two 'controls' (e.g. sails, ratchets or spinning tops) to keep the same through our experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We identified at least three 'controls' (e.g. sails, ratchets or spinning tops) to keep the same through our experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We proposed at least one new experiment. We identified the independent and dependent variable for our new experiment. We identified at least three 'controls' for our new experiment. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we labeled our design for a windmill.				
Obtaining, Evaluating, and Communicating Information: Integrate qualitative and/or quantitative information in written text with visual displays to clarify claims and findings.	<ul style="list-style-type: none"> We labeled one important part of our 'magnificent mill' design. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We labeled two more important parts of our 'magnificent mill' design. We explained how one of the important parts of our 'magnificent mill' works. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained how all three important parts of our 'magnificent mill' work. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We created and shared our diagram and explanation with classmates. We revised our work and made it more clear for our classmates to understand. <input type="checkbox"/>
Notes:				



Land Yacht

Technology

- Using mechanisms – gearing down
- Assembling components
- Combining materials

Science

- Renewable energy
- Measuring area
- Measuring distance
- Measuring time
- Forces
- Friction
- Air resistance
- Pressure
- Scientific investigation

Vocabulary

- Area
- Wind resistance
- Renewable energy
- Gearing down
- Friction

Other Materials Required

- 4-meter (4 yards) strip of smooth floor
- Masking tape
- Meter stick (yard stick) or measuring tape
- Timer or stopwatch
- 3-speed desk fan
- Optional: card, scissors, pencils, and rulers to make your own sails

Connect

It is a windy weekend at the beach and Jack and Jill are out to have a bit of fun. They have this old cart they normally use, but today it's Jill's turn to push Jack and Zog the Dog, and the weather is really windy, which makes it very hard work for her.

Jill gives up in the end and Jack can understand why. Zog the Dog does his best to help out and suddenly he sees an old towel half buried in the sand. Jill spots it at exactly the same time and they discuss between them how using the towel, the wind power, and a few other things, it may be possible to make a kind of land yacht that will safely take them all for a fun ride.

**How can you make a safe cart that is powered by the wind ... and carries at least one person?
Let's find out!**



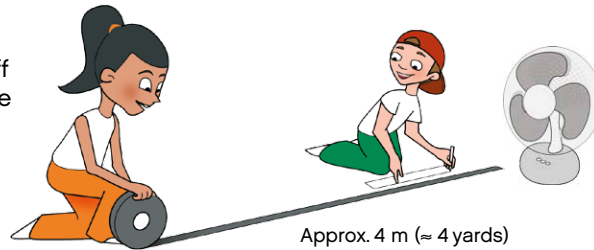
Construct

Warning!

Fans are potentially dangerous. Make sure that children handle them with great care!

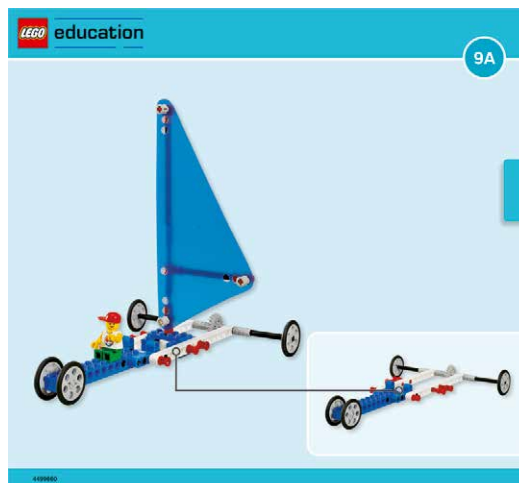
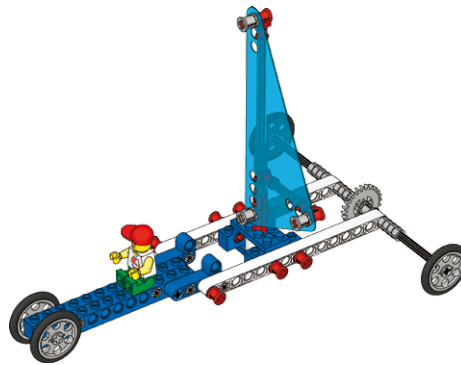
Make Your Test Track

Stick a 4-meter (≈ 4 yards) strip of masking tape across a stretch of floor and mark it off every 10 cm (≈ 4 in) from the fan. Now we are ready to build models!



Build the Land Yacht

(all of Book 9A and book 9B to page 5, step 12)
Build it with the small sail first.



Contemplate

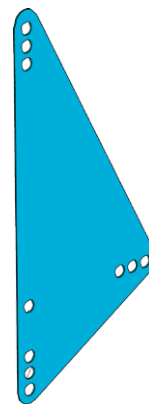
What difference does sail size make?

Predict and test: what difference could there be between the 40 cm² (≈ 15 in²) (small), 80 cm² (≈ 31.5 in²) (medium), and 160 cm² (≈ 63 in²) (large) sails on the yacht. How far will each roll ... and (optional) how fast? Test at least three times with each sail attached to obtain a scientifically valid answer.

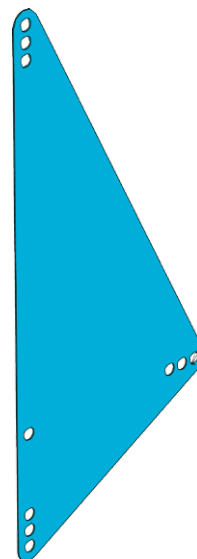
In our tests, the small sail rolled about 1.5 m, the medium about 2 m and the large about 2.5 m. Double the area gathers more wind energy but does not double the distance. Why? The further from the fan, the weaker the wind! Larger sails moved faster at first. But all the sail sizes stopped rolling after about 10 seconds. None of them sail faster than the wind!



40 cm²
(≈ 15.7 in²)
small
page 5,
step 12



80 cm²
(≈ 31.5 in²)
medium
page 9, step 21



160 cm²
(≈ 63 in²)
large
page 14, step 30



Tip:

Choose ONE speed setting to do all the tests. Any speed will do. We used high speed.



Note:

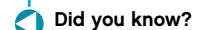
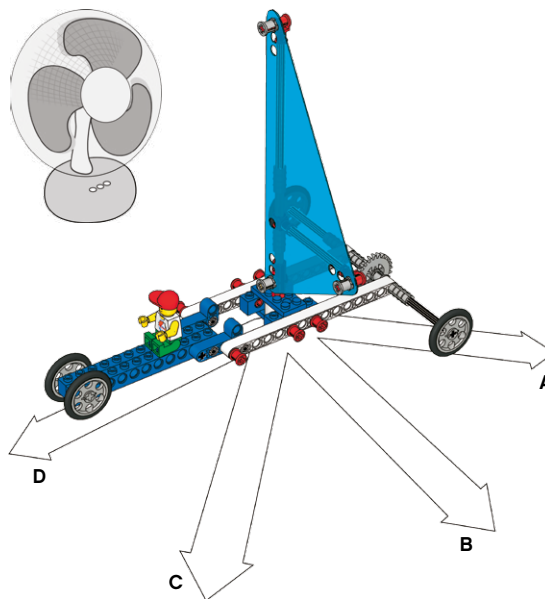
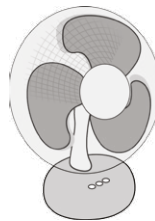
Your 'serious' scientists might also suggest testing the land yacht with just the bare mast, i.e. with no sail at all, so you might wish to try that as well.

What if the wind is blowing from an angle?

Launch your land yacht at different angles across the wind stream. Can you explain what happens?

At most angles except D the yacht still moves forward! One part of the wind's force is deflected off the sail, propelling it forward.

The other part of the force tries to blow it sideways. In fact a land yacht sailing across the wind at angles B and C can go very fast – but could also flip over.



Did you know?

The LEGO® figure weighs 3 g (≈ 0.1 oz).
The yacht weighs about 55 g (≈ 1.94 oz).
The weight brick is 53 g (≈ 1.9 oz).
Predict and test how the yacht would perform with a weight brick load.

Does sail shape matter?

Try making card or paper sails with the same area but a different shape. Find out about Square Riggers, Kon Tiki, Chinese Junks, and Arab Dhows from books or by searching the internet.

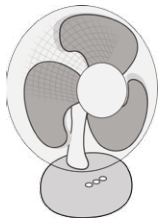
Continue

The Wind Sucker

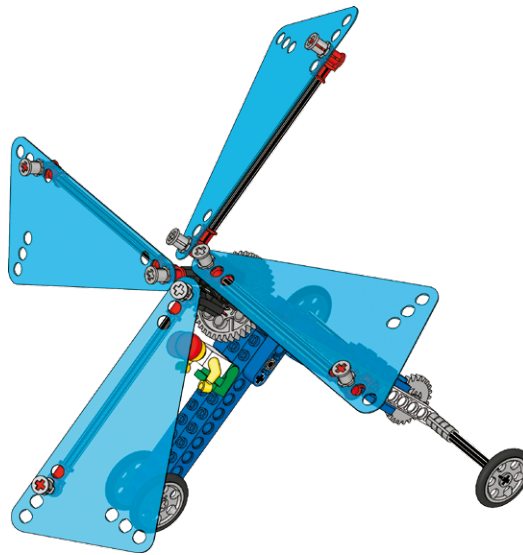
Rebuild the model to page 24, step 15. Hold the model 2 m (\approx 2 yds) away facing the fan (set on high speed). Predict what will happen when you let go. Then try it! Can you explain?

It builds up speed running towards the fan. The wheels may skid when it is close to the fan.

- The energy from the wind is collected by the sails, geared down (3:1), which increases the force and turns the wheels, but in the opposite direction
- When it skids – the wind force one way is equal to the friction force of the tires pushing the other way



About 2 m
(\approx 2 yds)
from the fan



Idea:

Predict and test what happens if you face it away from the fan.

Making it more efficient?

Add a weight brick and see what happens. Swap the thin wheels for big wheels.

If it is skidding, adding weight increases friction by pressing the tires harder onto the floor. Large wheels also have more area in contact with the floor, i.e. friction and grip increase and it moves forward. It will also move faster (larger wheels).

Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
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a	to seek more information.										
b	to seek evidence to support a claim.										
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a	to explore its limitations.										
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e	to generate data about what they are designing or investigating.										
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a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
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a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
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Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Land Yacht

Name(s): _____

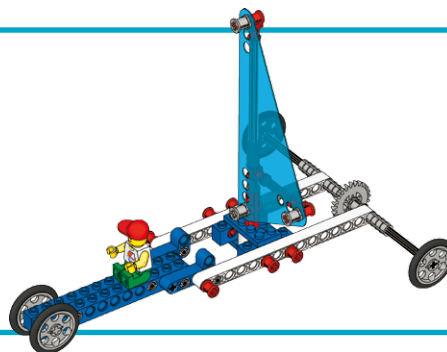
How can you make a safe cart that is powered by the wind and carries at least one person? Let's find out!



Build the Land Yacht

(all of book 9A and book 9B to page 5, step 12)

- Use the small sail



What difference does the size of the sail make?

- Turn on the fan. Predict and test how FAR each model will roll with the same wind speed
- Test at least three times with each sail to achieve a scientifically valid answer

NOTE: FANS and FINGERS! TAKE CARE!

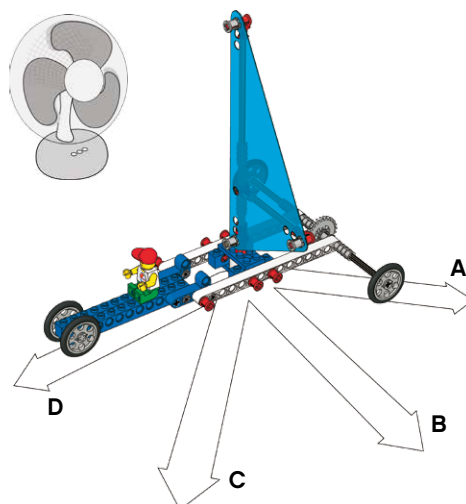
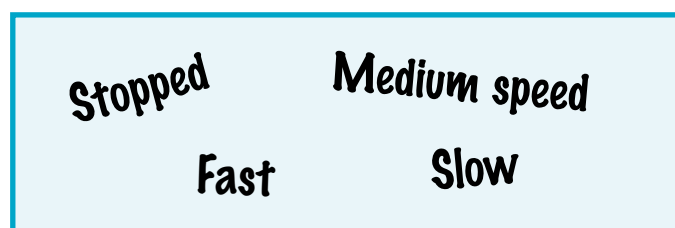
Tip:

Choose ONE speed setting to do all the tests. Any speed will do. We used high speed.

	My Prediction	Actual Distance
Small 40 cm ² (≈ 15 in ²) sail page 5, step 12		
Medium 80 cm ² (≈ 31.5 in ²) sail page 9, step 21		
Large 160 cm ² (≈ 63 in ²) sail page 14, step 30		

What difference does wind angle make?

- Launch your yacht at different angles across the wind stream
- How fast does it travel each time?
- Write the words next to the arrows to match what you saw happening

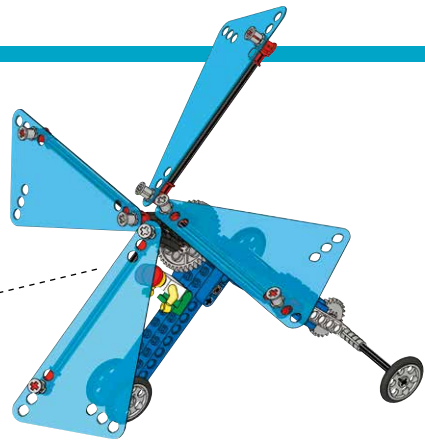


The Wind Sucker

- (Build book 9B to page 24, step 15).
- Hold it 2 m (≈ 2 yds) away facing the fan
 - Predict what will happen and then let go



About 2 m
(≈ 2 yds)
from the fan



My Prediction	Actual Distance



Also try:

- Fat back wheels
- A weight brick
- Two or three sails
- Facing backward

My Land Sailor

Draw and label your design for a wind-powered vehicle.
Explain how the three best parts work.





Did you know?

The LEGO® figure weighs 3 g (≈ 0.1 oz). The yacht weighs about 55 g (≈ 1.94 oz). The weight brick is 53 g (≈ 1.9 oz). Predict and test how the yacht would perform with a weight brick load.

Land Yacht

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a land yacht with different sized sails. We tested it with a fan at different angles.				
Energy and matter: Flows, cycles, and conservation: Energy may take different forms and can be tracked as energy flows through a design system.	<ul style="list-style-type: none"> We built a land yacht. We practiced running our land yacht on the test track in front of the fan. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. Built different sized sails for our experiments. We aimed the fan at our vehicle from different angles. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We built and tested a wind sucker. We changed and tested our wind sucker design with at least two additional ideas from the list on our Student Worksheet. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We proposed at least two additional things to test how the energy from the fan can be transferred to a LEGO® sail vehicle. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we investigated how the size of our wind sail affects the motion of our land yacht. We also investigated wind direction and a unique design called a 'wind sucker'.				
Planning and Carrying Out Investigations: Identify independent and dependent variables and controls, how measurements will be recorded, and how many data are needed to support a claim.	<ul style="list-style-type: none"> We completed at least two out of the three possible investigations on our student worksheet. We identified at least one 'control' (e.g. wind speed, sail size or wind angles) to keep the same in through our experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We completed all three investigations. We chose the correct measurement tools. We identified at least two 'controls' (e.g. wind speed, sail size or wind angles) to keep the same through our experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We identified at least three 'controls' (e.g. wind speed, sail size or wind angles) to keep the same through our experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We proposed at least one new experiment. We identified the independent and dependent variable for our new experiment. We identified at least three 'controls' for our new experiment. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we labelled our design for a wind-powered vehicle.				
Obtaining, Evaluating, and Communicating Information: Integrate qualitative and/or quantitative information in written text with visual displays to clarify claims and findings.	<ul style="list-style-type: none"> We labeled one important part of our land sailor design. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We labeled two extra important parts of our land sailor design. We explained how one of the important parts of our land sailor works. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained how all three important parts of our land sailor work. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We created and shared our diagram and explanation to classmates. We revised our work and made it more clear for our classmates to understand. <input type="checkbox"/>
Notes:				



Flywheeler

Technology

- Using mechanisms – gearing up
- Assembling components

Science

- Measuring distance
- Measuring time
- Forces
- Moving energy
- Friction and air
- Resistance
- Scientific investigation

Vocabulary

- Gearing up
- Flywheel
- Mass
- Position

Other Materials Required

- 3-meter (\approx 3 yard) strip of smooth floor
- Masking tape
- Meter stick (yard stick) or measuring tape
- Timer or stopwatch

Connect

Jack and Jill have had a little quarrel and have been sent outside to cool down. Jill gets Zog the Dog to pull her on the cart, but it is far too slow.

Jack plays with his spinning tops. They spin very fast, but really he would much rather be friends with Jill and play with her again. Jill feels exactly the same – it is much better when they are good friends, and quite frankly, they are bored playing games that are not fun.

They look at each other and suddenly Jill gets an idea. How about a combined game using both the cart AND the power of the spinner? Will that work, do you think?

Could the spinning of a spinning top help a push-along car move and will it travel further – and for a longer time?

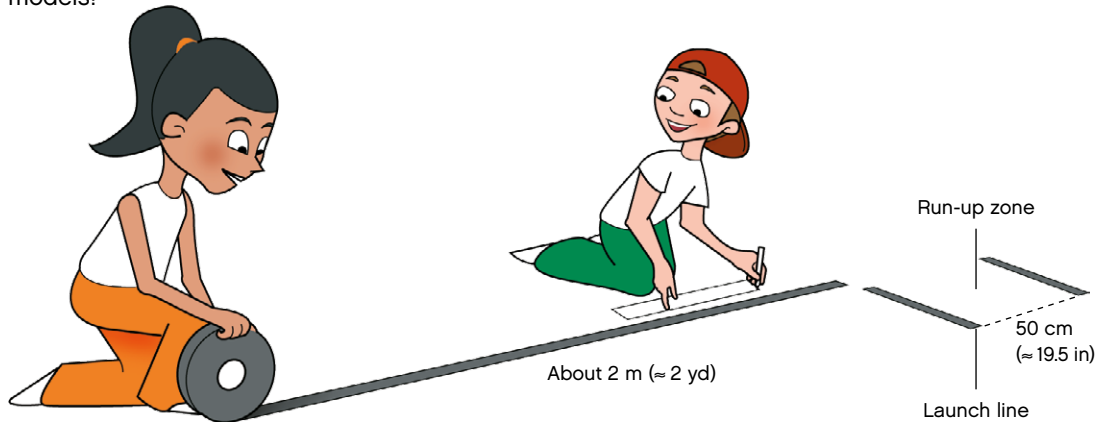
Let's find out!



Construct

Make the Test Track

Mark out a 50 cm (≈ 19.5 in) section of run-up track. This is the run-up zone and in front of the launch line. Then stick a 2 m (≈ 2 yd) strip of masking tape along the floor and mark it off every 10 cm (≈ 4 in). Now we are ready to build models!



Build the Flywheeler

(all of book 10A and book 10B to page 10, step 20)

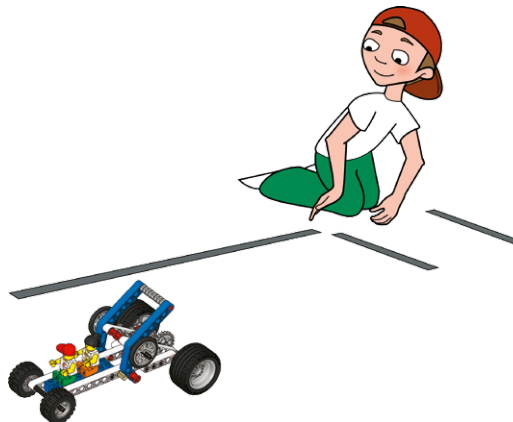
- When pushed it should roll to a stop quite slowly
- If it slows too soon, loosen the axle bushings, make sure gears are meshing properly, and make sure all other elements are pressed firmly together



Contemplate

Fair Testing

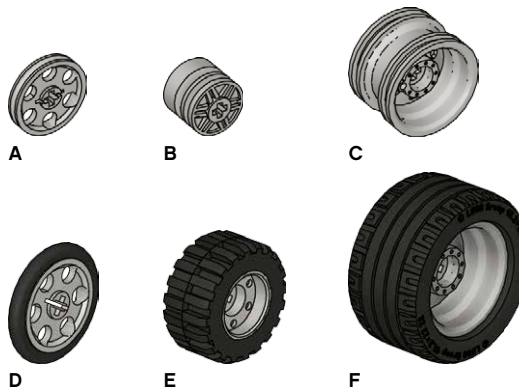
To fair test each model, use a 2-second run-up over 50 cm (≈ 19.5 in) and release at the launch line – at the same speed. It takes practice! This is why it is a good idea to test each model three times to be sure.



What makes a good flywheel?

The best flywheel will carry the model further, and roll for a longer time – with exactly the same run up! Try it without any flywheels at all! Try the big hub with and without its tire. Invent your own combinations too.

Heavier flywheels work better than lighter ones, but they need a lot of arm energy to get up to speed, i.e. the amount of moving or kinetic energy it stores depends on its weight and on the speed it is travelling.



How far and for how long will it roll?

Measure how far each flywheel rolls.
Even better, but optional, time how long it rolls!

Build to page 12, step 22.
Test and measure.

Build to page 14, step 24.
Test and measure.

The flywheel cars travel very slowly. The bigger the flywheel – often the slower they travel – but the longer they run for and the further they go.

Did you know?

The best energy storing flywheels are put inside an airtight case and run in a vacuum to remove air resistance!

Did you know?

We use 8-tooth and 24-tooth gears to gear up. There are two gearing-up stages, each 1:3, i.e. one turn of the wheel on the ground gives 9 turns of the flywheel.

Continue

Shakey Brakey!

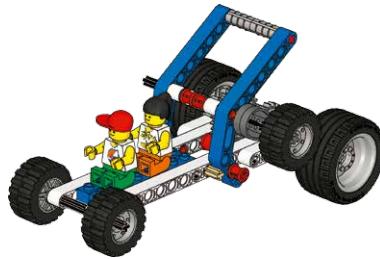
Build book 10B to page 17, step 3 with a flywheel mounted off center.

Predict what will happen – then test it.

It stops the car very quickly! Flywheels must be DYNAMICALLY balanced when spinning, otherwise they produce large forces going in many directions, which increases FRICTION on the axles.

Try rolling Shaky Brakey down the hill. What happens? Compare it to rolling with the balanced flywheel.

It rolls very slowly and does not get faster. Dynamic imbalance forces increase hugely with just a little increase in speed. At low speeds they are small, so the vehicle stays at a slow speed.



Did you know?

In real life, an off-balance super fast flywheel can explode!

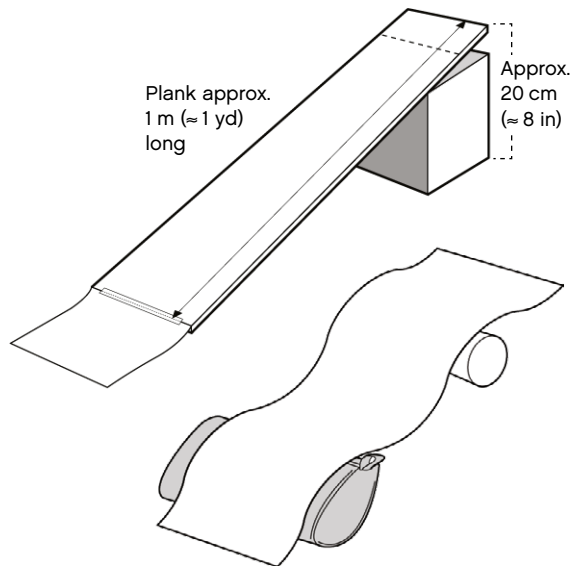
The Hill Climber

Make a ramp for the cars to run up. Predict and test how a flywheel and a non-flywheel car will perform with the same speed run up (this can be tricky!). You may want to work with some of the other teams in class on this activity.

The flywheel car travels further up the plank. It has a lot of stored energy.

Make a series of low hills for the cars to negotiate. Thin card taped over shoes or objects works well.

The flywheel car goes slowly both up and down the hills. It acts as kind of 'controller' to help cars get over hills at an even speed.



Taking on an Obstacle Course

Make a big pile of LEGO® bricks on the floor or on the table and find out which type of flywheel it will take to cross the LEGO 'mountain'

The flywheel car with the big tires is best at forcing its way through the course and over the pile.

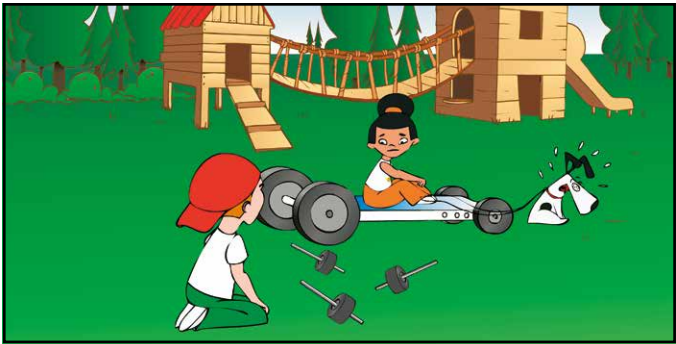
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Notes:											

Observation Checklist Part 2		Name(s)									
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Practice 5: I observed students using mathematics and computational thinking:											
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Flywheeler

Name(s): _____

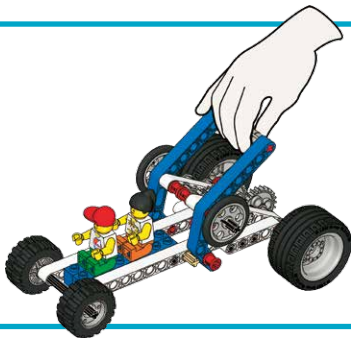
Could the spinning of a spinning top help a push-along car move, and will it travel further – and for a longer time? Let’s find out!



Build the Flywheeler

(all of book 10A and book 10B to page 10, step 20)

- Make sure it rolls smoothly
- If it stops too quickly, loosen bushings and make sure all other elements fit tightly

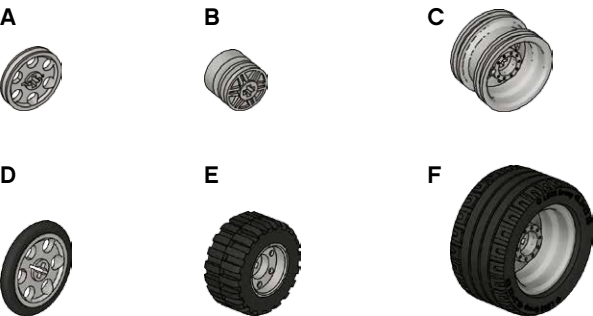


What makes a good flywheel?

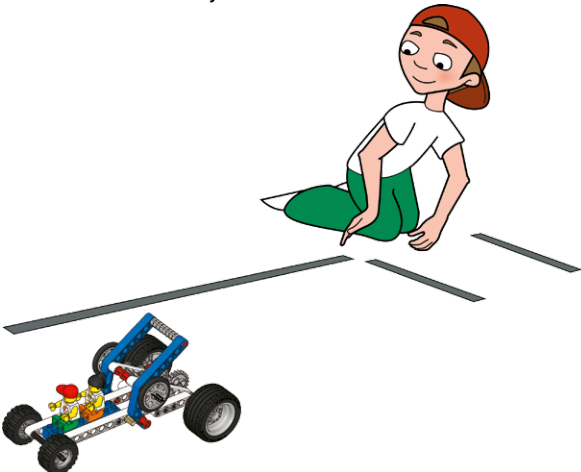
Predict and test how far each model will roll:

- With at least three different flywheels or combinations
- With the same run-up
- Launched at the same speed

Optional: time how long each car rolls for



Test at least three times with each flywheel combination to achieve a scientifically valid answer.



My Combination	My Prediction	Actual Distance		Time
A+B				

Did you know?
In real life, an off-balance super fast flywheel can explode!

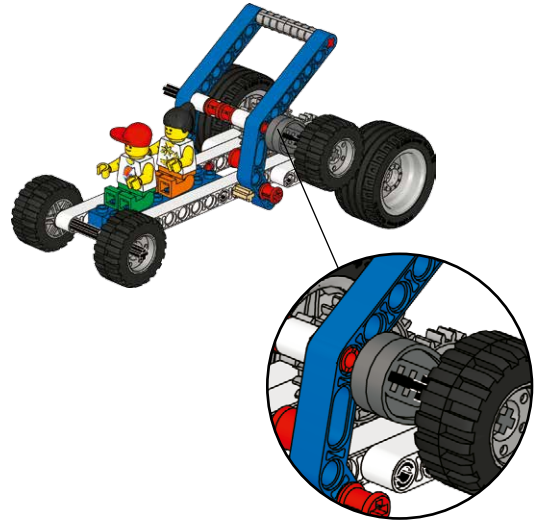
Shakey Brakey

Build to book 10B page 17, step 3.

What happens if your flywheel is unbalanced?

My prediction:

And this happened after testing:



Also try:

- Climbing up hills
- On smooth floors and carpets
- Climbing over an all-terrain obstacle course, e.g. a pile of LEGO® bricks!

My Fab Flywheeler

Draw and label your flywheeler design.





Explain how the three best parts work.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	5
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Flywheeler

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built the Shakey Brakey model to test what happens when a flywheel is mounted off-center.				
Cause and Effect: Mechanism and Explanation: Use cause and effect relationships to explain observations in designed systems.	<ul style="list-style-type: none"> We built the Shakey Brakey model. We predicted what would happen. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We explained what we saw and explained what caused it. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We tested our Shakey Brakey at both slow speeds and fast speeds. We described causes and effects related to our observations. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We explored real-life machines that behave similar to our Shakey Brakey. We reported our findings to our classmates or our teacher. <div style="text-align: center;"><input type="checkbox"/></div>
2. Student work related to this Practice: In this project, we built a flywheeler with different flywheel combinations.				
Developing and Using Models: Use a model to generate data to test ideas about designed systems.	<ul style="list-style-type: none"> We built a flywheeler that moves slowly. We created a space to test our flywheeler with the same "run-up". <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We practiced to make sure our flywheeler is launched with the same speed for each experiment. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We completed an experiment with all twelve different flywheel combinations. We explained the advantages and disadvantages of these three models, when asked. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We completed an experiment with all six different flywheel combinations. We explained which combination traveled the longest, when asked. <div style="text-align: center;"><input type="checkbox"/></div>
3. Student work related to this Practice: In this project, we experimented on our flywheeler with different flywheel combinations. We used our observations help us explain how the three best parts of our flywheeler work.				
Analyzing and Interpreting Data: Analyze data to define an optimal operational range for a system that best meets criteria for success.	<ul style="list-style-type: none"> We wrote down our observations (distance or time) for at least three different flywheel combinations. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We analyzed the data we collected and determined which flywheel combination was the best (traveled the furthest) <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We explained how three parts of our flywheeler work. We explained why the flywheel combination we picked was the best. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We completed an experiment with all six flywheel combinations. We analyzed all of our data to determine which flywheel was the best. <div style="text-align: center;"><input type="checkbox"/></div>
Notes:				



Power Car

Technology

- Combining components
- Gears
- Wheels

Science

- Friction
- Measuring distance, time and force
- Scientific investigation

Vocabulary

- Counter balance
- Friction
- Gears
- Grip
- Torque

Other Materials Required

- Meterstick (yard stick) or measuring tape
- Plank – 240 cm (≈ 95 in) or longer
- Small books or other objects to make a load
- Stopwatch or timer

Connect

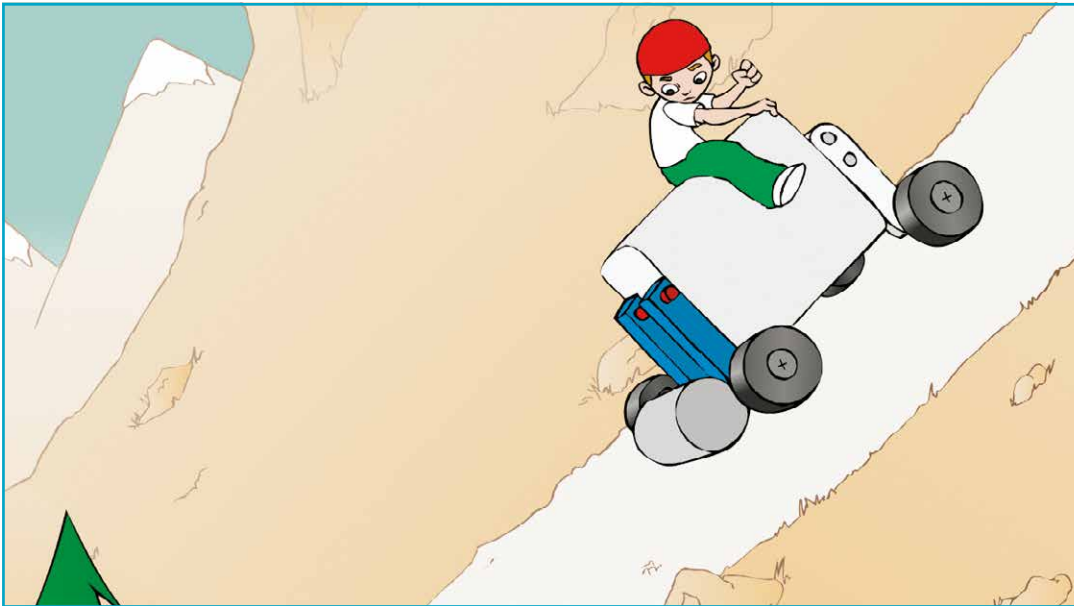
Jack and Jill are out in the hills behind their house testing their power car. It's great fun and a great way for Zog to keep fit too. The car works just fine on level ground but it just can't seem to climb those hills.

The wheels skid, the motor makes terrible noises, and the front end of the car lifts off the ground.

Jack thinks the car needs to be heavier. Jill thinks the gears are all wrong for going up hills.

How can you make a power car that climbs hills?

Let's find out!

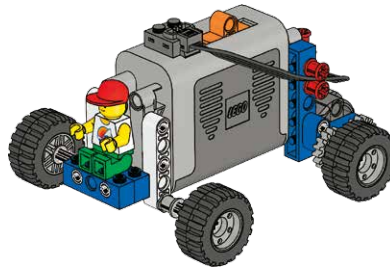


Construct

Build the Power Car

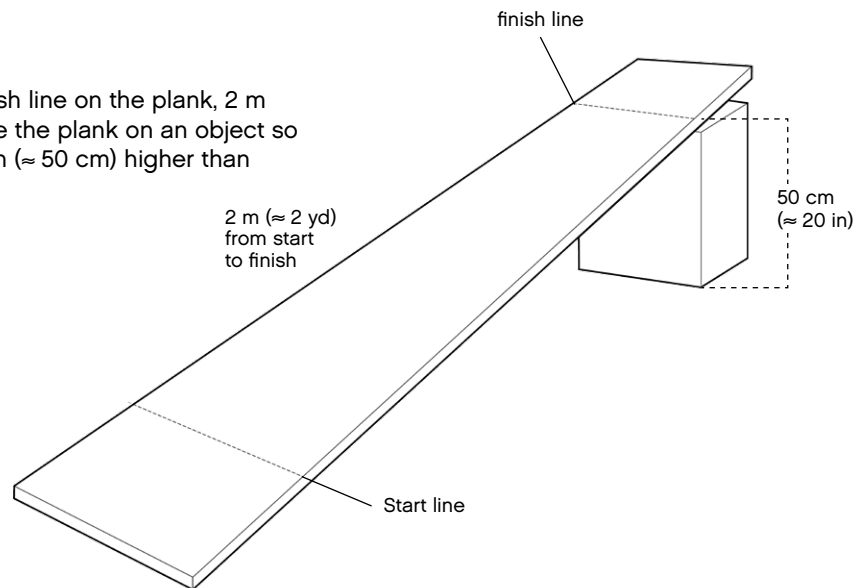
(all of book 11A and book 11B to page 9, step 10)

- Turn on the motor by pushing the battery box switch forward
- Make sure all the wheels turn freely and do not rub on the sides of the power car



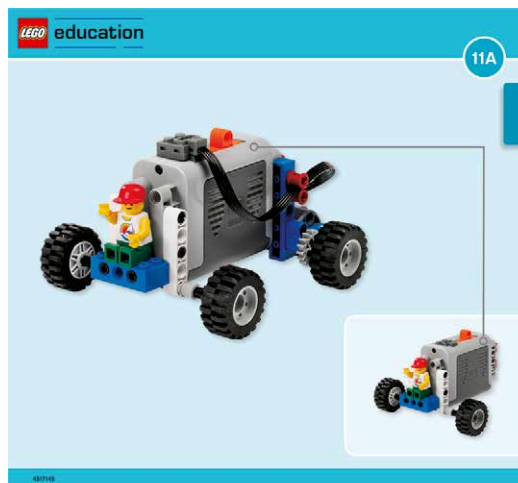
Build Your Test Hill

Mark a start and finish line on the plank, 2 m (\approx 2 yds) apart. Place the plank on an object so the finish line is 20 in (\approx 50 cm) higher than the floor.



Tip:

The power car can travel very fast, even up hills, so it might be a good idea to put the ramp against the wall in a corner to prevent it going over the edge.



Contemplate

Which is the fastest uphill power car?

The power car needs to be as fast as possible when driving uphill.

First predict how fast power car A will travel 2m (≈ 2 yd) uphill. Then test your prediction. Next, follow the same procedure for power cars B, C and D.

Test several times to make sure your results are consistent. Test results may vary depending on surface of the hill.

Power car A (page 9, step 10) will need approximately 4 seconds to travel 2 m (2 yd) uphill.

Power car B (page 10, step 11) will need approximately 3 seconds to travel 2 m (≈ 2 yd) uphill.

Power car C (page 11, step 12) will need approximately 10 seconds to travel 2 m (≈ 2 yd) uphill.

Power car D (page 12, step 13) will need approximately 7 seconds to travel 2 m (≈ 2 yd) uphill.

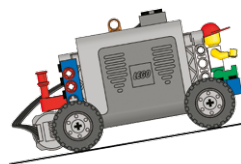
The fastest of the four is power car B, using big wheels and 1:1 gearing.

Optional: How steep a hill?

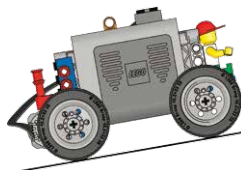
How steep a hill is your power car able to climb? Place the plank on an object so the finish line is 70, 80, 90 cm or more ($\approx 28, 31, 35$ in) higher than the floor. Test which of the power cars A, B, C or D is best at climbing steep hills.

Power car C can climb the steepest hills.

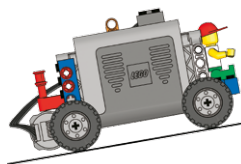
A



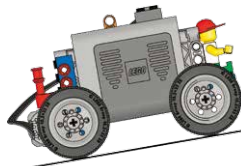
B



C



D



Did you know?

The circumference of the small wheel is 9.6 cm (≈ 3.77 in)



The circumference of the big wheel is 13.6 cm (≈ 5.35 in)



Continue

How strong is your power car?

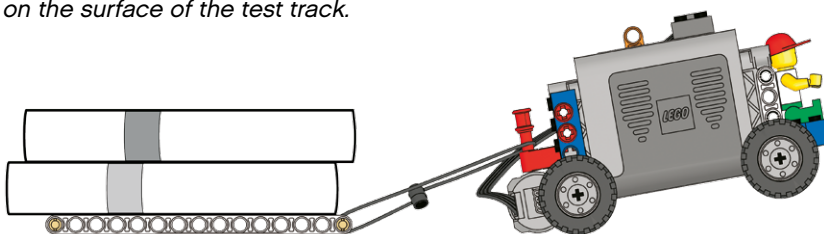
Build a sled and attach it to your power car using a string around the hook at the rear.

Load the sled with books.

First predict how heavy a load power cars A and C can pull.

Then test which power car can pull the heaviest load.

Power car C (page 11, step 12) can pull the heaviest load. Test results may vary, depending on the surface of the test track.

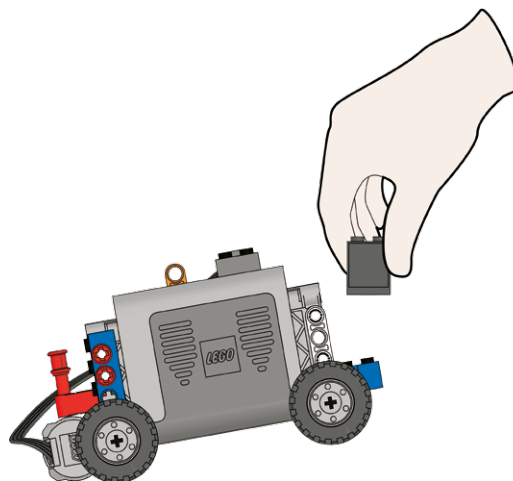


Also try adding counterbalance to the front of the power car.

This will keep the front end of the power car down and make it more stable.

Try different combinations of wheels and gearing to achieve the best pulling power.

How heavy a load can your best power car pull?



Tip:
Use the weight element as a counterbalance.

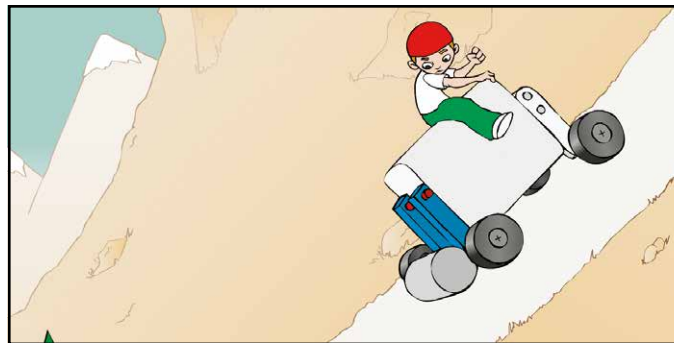
Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Power Car

Name(s): _____

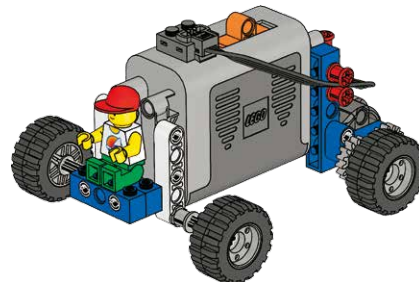
How can you make a power car that climbs hills?
Let's find out!



Build the Power Car

(all of book 11A and book 11B to page 9, step 10)

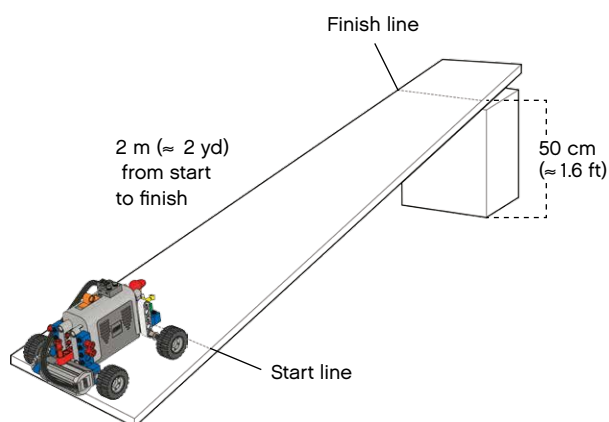
- Turn on the motor by pushing the battery box switch forward
- Make sure all the wheels turn freely and do not rub on the sides of the power car



Which is the fastest uphill power car?

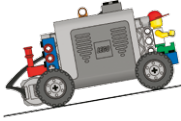
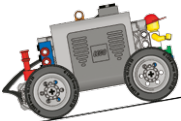
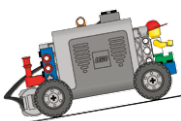
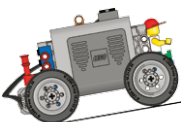
The power car needs to be as fast as possible when driving uphill.

- First predict how fast power car A will travel 2 m (\approx 2 yd) uphill. Then test your prediction. Next, follow the same procedure for power cars B, C and D.
- Test several times to make sure your results are consistent.



Tip:

The power car can travel very fast, even up hills, so it might be a good idea to put the ramp against the wall in a corner to prevent it going over the edge.

	My Prediction	What happened?
A 		
B 		
C 		
D 		

Gear Ratios

Car A 16:16

Car B 16:16

Car C 24:8

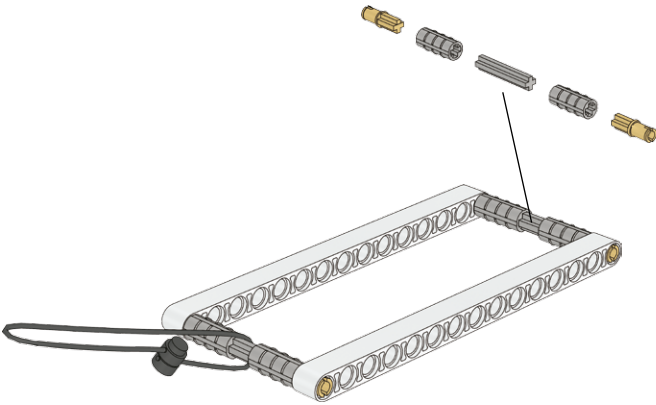
Car D 24:8

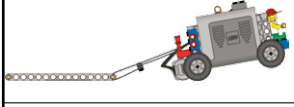

How strong is your power car?

Build a sled and attach it to your power car using a string around the hook at the rear.

Load the sled with books.

- First predict how heavy a load power cars A and C can pull. Then test which power car can pull the heaviest load.
- How heavy a load can your best power car pull?



	My Prediction	My Measurements
		
		





My Power Car

Draw and label your favorite power car design.
Explain how the 3 best parts work.

Power Car

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we made predictions and observed our power car move up a hill with different wheel and gear combinations.				
Stability and Change: Explain stability and change in designed systems by examining changes over time.	<ul style="list-style-type: none"> We predicted how much time it would take power cars A and B to drive up the ramp. We wrote our predictions and test results on our Student Worksheet. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We completed our predictions and test results for power cars C and D. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We predicted and tested at least two of our power cars with the sled pull experiment. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We proposed and completed at least two additional experiments to test the motion of our power car on the ramp or in the sled pull experiment. <input type="checkbox"/>
2. Student work related to this Practice: In this project, we built a power car with different wheel and gear combinations. We used it in a hill climb experiment and a sled pull experiment.				
Developing and Using Models: Use a model to generate data to test ideas about designed systems.	<ul style="list-style-type: none"> We built power cars A and B that moved by battery power. We practiced running power cars A and B on the ramp for fair testing. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We changed wheels and gear combinations for power cars C and D. We used fair testing in all of our hill climb experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We built the sled for pulling books or other objects. We used our power car in our sled pull experiments. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We completed the building necessary to test one or two new ideas for the sled pull experiment. <input type="checkbox"/>
3. Student work related to this Practice: In this project, we labeled our favorite Power Car design.				
Obtaining, Evaluating, and Communicating Information: Integrate qualitative and/or quantitative information in written text with visual displays to clarify claims and findings.	<ul style="list-style-type: none"> We labeled one important part of our power car design. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Bronze. We labeled two more important parts of our power car design. We explained how one of the important parts of our power car works. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Silver. We explained how all three important parts of our power car work. <input type="checkbox"/>	<ul style="list-style-type: none"> We met Gold. We created and shared our diagram and explanation with classmates. We revised our work and made it more clear for our classmates to understand. <input type="checkbox"/>
Notes:				



Dragster

Technology

- Gears
- Levers
- Using and combining components
- Wheels

Science

- Energy
- Friction
- Measuring distance
- Scientific investigation

Vocabulary

- Acceleration
- Gears
- Mass
- Momentum

Other Materials Required

- Meterstick (yard stick) or measuring tape
- Up to 20 m (≈ 20 yds) of floor. You might have to use the corridor!

Connect

Jack and Jill are experimenting with their dragster. With a great start from a launcher, they hope it will roll all the way from the start to the finish line. But even after a perfect launch it does not go very far.

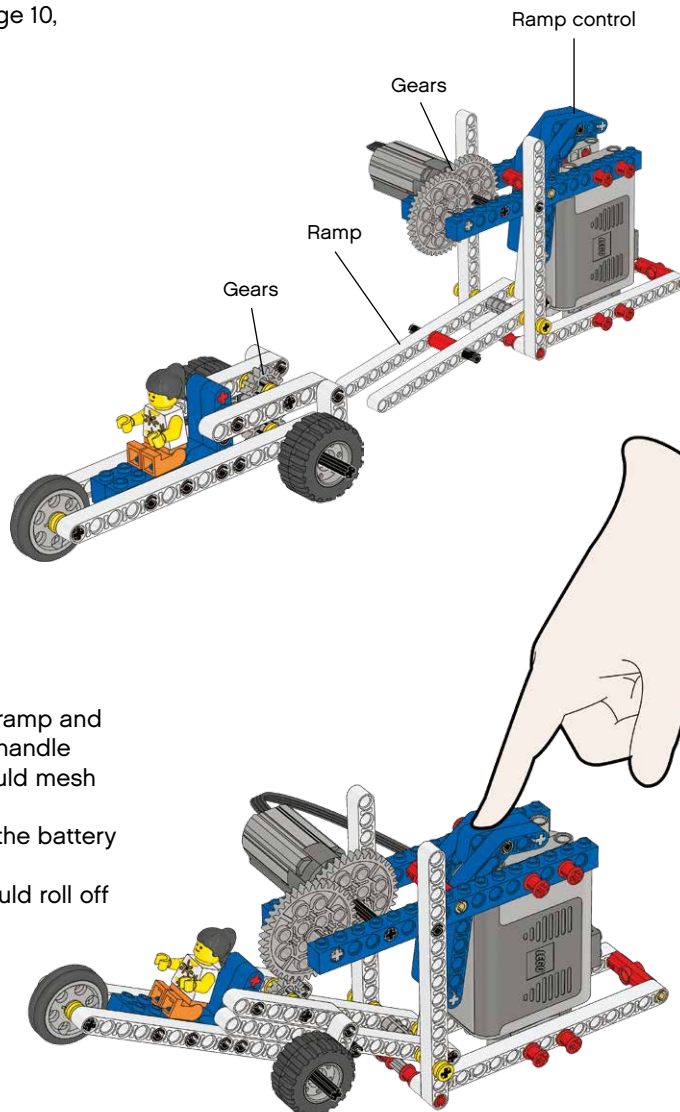
**How can we make the dragster go further?
Let's find out!**



Construct

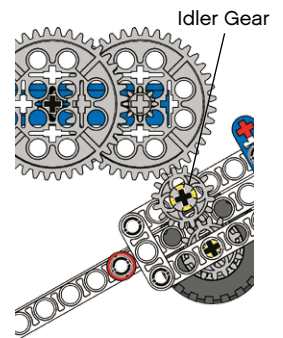
Build the Dragster and Launcher.

(all of book 12A and book 12B to page 10, step 13)



- Place the dragster on the launch ramp and lift it up by pressing down on the handle
- The big gear on the launcher should mesh with the gear on the dragster
- Start the motor by pushing down the battery switch
- Lower the ramp. The dragster should roll off smoothly onto the floor

Did you know?



An idler gear changes the direction of rotation, but does not affect the output speed.

Tip:

If your dragster vibrates, one of the tires might be sitting unevenly on its hub. This increases axle friction and leads to large energy losses.



Contemplate

How far will the dragster go?

By changing the back wheels of your dragster you can change how far it can travel.

First predict how far dragster A will travel. Then test your prediction. Next, follow the same procedure for dragsters B and C. Which will travel the furthest?

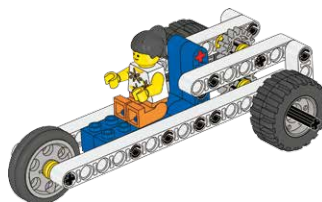
Test several times to make sure your results are consistent. Test results may vary depending on surface of your test track.

Dragster A (page 9, step 12) will travel approximately 0.7 m (\approx .75 yd).

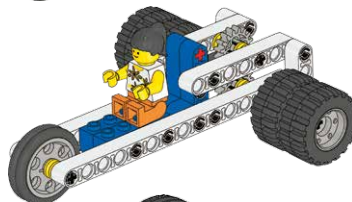
Dragster B (page 12, step 15) will travel approximately 2 m (\approx 2.2 yd).

Dragster C (page 12, step 16) will travel even further, approximately 6 m (\approx 6.5 yd).

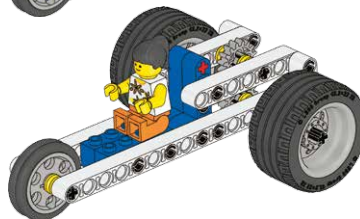
A



B



C



Did you know?

The small wheel weighs 9g (\approx 0.2 oz).



The large wheel weighs 13g (\approx 0.45 oz).



Can you explain what happened when you changed the wheels?

Two small wheels store more energy than one, because they have twice the mass. That is why dragster B goes further than dragster A.

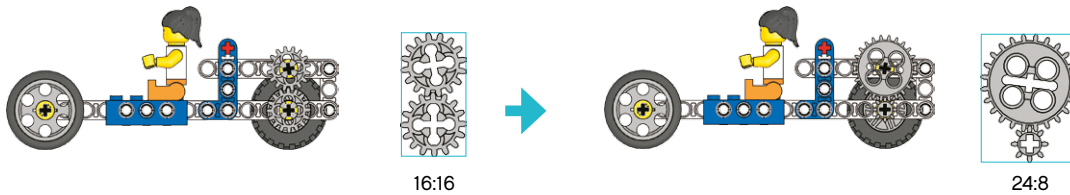
Dragster C goes further than dragster B due to the larger circumference of the bigger tires, and even though axle speed is the same.

The more tire mass and the bigger the tire circumference, the further the dragster will go.

Continue

Can the dragster go even further?

To gear up your dragster, first disassemble it (book 12B to page 3, step 3), and then:

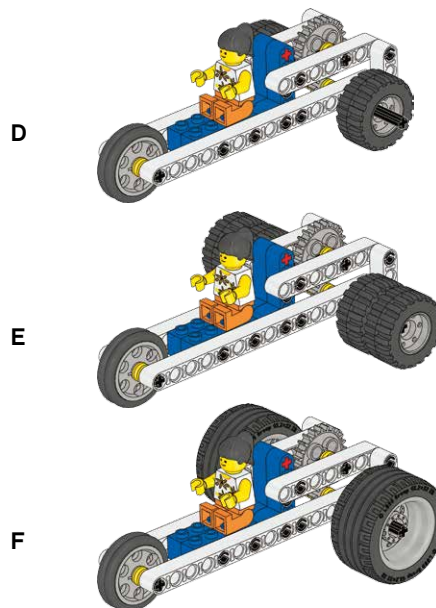


Replace the 16:16 gearing with a 24:8 gearing. Now build your geared-up dragster (book 12B to page 9, step 12).

First predict how far geared-up dragster D will travel. Then test your prediction. Next, follow the same procedure for your geared-up dragsters E and F. Which will travel the furthest?

Dragster F will travel furthest, approximately 11 m (\approx 12 yd).

Try other ideas and combinations to make your dragster travel even further. How far does your best dragster travel?



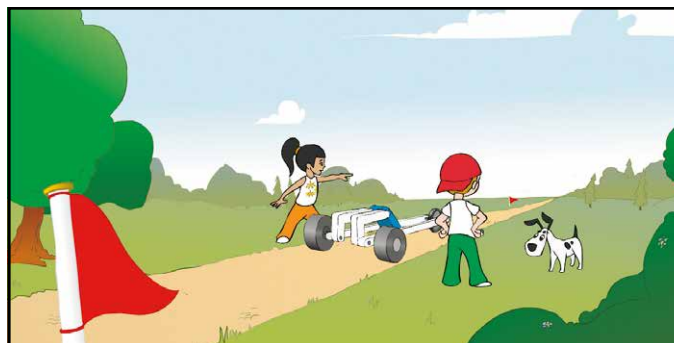
Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Dragster

Name(s): _____

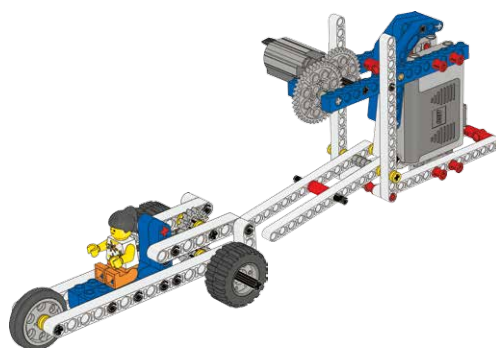
How can we make the dragster go further?
Let's find out!



Build the Dragster and Launcher

(all of book 12A and book 12B to page 10 step 13)

- Place the dragster on the launch ramp and lift it up by pressing down on the handle
- The big gear on the launcher should mesh with the gear on the dragster
- Start the motor by pushing down the battery switch
- Lower the ramp. The dragster should roll off smoothly onto the floor

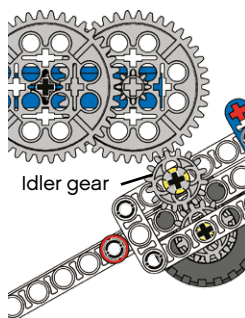


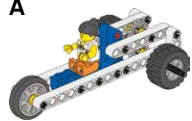
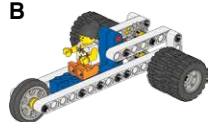
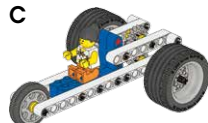
How far will your dragster go?

- First predict how far dragster A will travel. Then test your prediction. Next, follow the same procedure for dragsters B and C. Which will travel the furthest?
- Test several times to make sure your results are consistent. Test results may vary depending on surface of your test track.

Did you know?

An idler gear changes the direction of rotation, but does not affect the output speed.



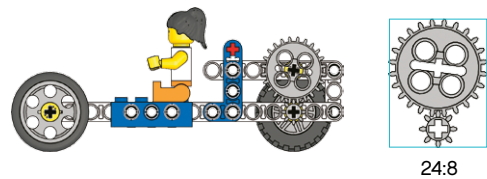
	My Prediction	My Measurements
A 		
B 		
C 		

Tip: If your dragster vibrates, one of the tires might be sitting unevenly on its hub. This increases axle friction and leads to large energy losses.

Can you explain what happened when you changed the wheels?


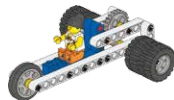
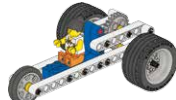
Can your dragster go even further?

To gear up your dragster, first disassemble it (book 12B to page 3, step 3), and then:



Replace the 16:16 gearing with a 24:8 gearing. Now build your geared-up dragster (book 12B to page 9, step 12).

- First predict how far geared-up dragster D will travel. Then test your prediction. Next, follow the same procedure for your geared-up dragsters E and F. Which will travel the furthest?
- Try other ideas and combinations to make your dragster travel even further.
How far does your best dragster travel?

	My Prediction	My Measurements
D 		
E 		
F 		





My Dragster

Draw and label your favorite dragster design. Explain how the 3 best parts work.

Dragster

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we drew and labeled our favorite dragster. We explained how the parts of our dragster and launcher system work together and how they work separately.				
Systems and System Models: Systems may have sub-systems and be a part of a larger complex system. Use models to present systems and their interactions such as inputs, processes, and outputs.	<ul style="list-style-type: none"> We drew and labeled the parts of our dragster. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We labeled which parts of our dragster needed to work with the launcher and which parts did not. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We explained how our dragster was moved by the launcher. We explained how our dragster could move without the launcher. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We researched and shared an example system that was similar to our dragster. <div style="text-align: center;"><input type="checkbox"/></div>
2. Student work related to this Practice: In this project, we investigated how the different wheels would affect how far our dragster travels.				
Planning and Carrying Out Investigations: Collect data about the performance of a proposed object under a range of conditions	<ul style="list-style-type: none"> We made predictions and measurements for at least two of the set-ups given on our Student Worksheet (among models A-C). <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We made predictions and measurements for one more of the set-ups given on our Student Worksheet (among models A-C). <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We changed our dragster's gear ratio so it would travel further. We made predictions and measurements for all three set-ups shown on our Student Worksheet (among models D-F). <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We proposed and tested at least one more idea to make our dragster travel further. <div style="text-align: center;"><input type="checkbox"/></div>
3. Student work related to this Practice: In this project, we explained what happened as a result of changing the wheels on our dragster.				
Constructing Explanations: Apply scientific ideas or principles to design an object, tool, process or system.	<ul style="list-style-type: none"> We explained what happened when we changed our dragster's wheels. Our explanation was based on what we saw in our experiment. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We correctly used the ideas of mass and energy in our explanation. We correctly connected energy and distance traveled. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We correctly explained why cars with bigger tires have more energy and travel further. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We proposed new dragster design ideas based on our observations and explanations. <div style="text-align: center;"><input type="checkbox"/></div>
Notes:				



The Walker

Technology

- Gears
- Levers
- Linkage
- Ratchet
- Using and combining components

Science

- Force
- Friction
- Measuring time
- Scientific investigation

Vocabulary

- Balance
- Gears
- Grip
- Levers
- Linkages
- Ratchet

Other Materials Required

- Large thin book with a hard cover – big book or ring binder
- Ruler
- Stopwatch or timer
- Up to 1 m (\approx 1 yd) of floor space

Connect

Jack and Jill are having a great day out hiking. But it's hot, they are getting tired and their backpacks seem to be getting heavier and heavier.

When Jack and Jill stop for a short break, a line of ants passes them!

"How can they walk and carry so much so easily?" says Jack.

Jack and Jill think it would be great if an ant could carry them too!

How can you make a walker that will carry Jack and Jill along the trail?

Let's find out!

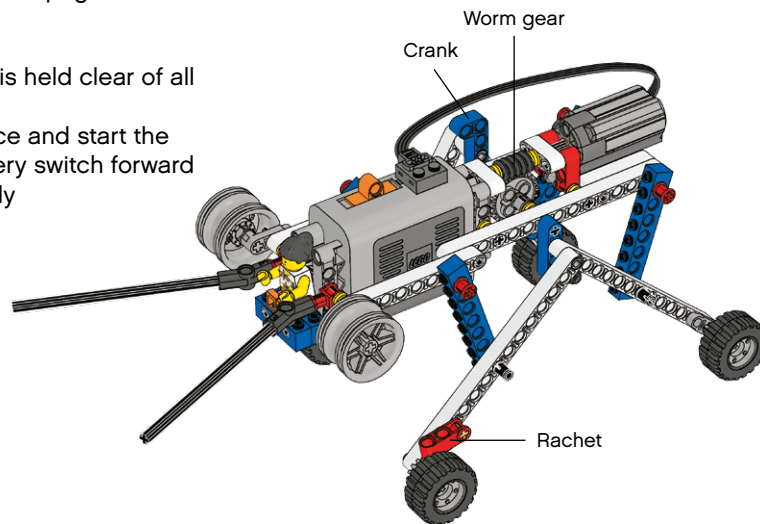


Construct

Build the Walker

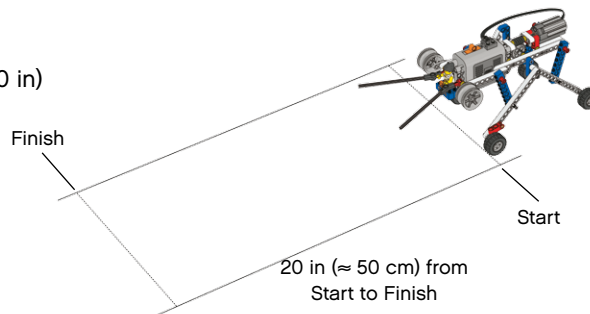
(all of book 13A and book 13B to page 13 step 18)

- Make sure the power lead is held clear of all moving parts
- Place it on a smooth surface and start the motor by pushing the battery switch forward
- The legs should move freely



Mark Your Test Track

- Mark a start line and finish line 50 cm (\approx 20 in) apart.



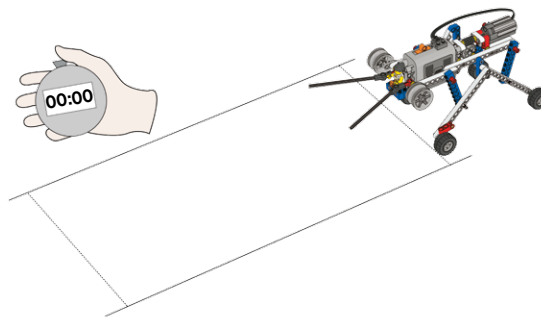
Contemplate

How fast can the walker walk?

The walker will walk at different speeds depending on the leg settings.

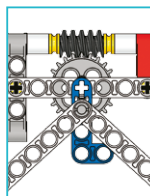
First predict how long it will take the walker to walk 50 cm (≈ 20 in) using leg setting A. Then test your prediction. Next, follow the same procedure for leg settings B and C.

Test several times to make sure your results are consistent. Test results may vary depending on the surface of your test track.



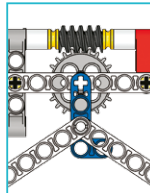
Leg setting A (page 13, step 18) results in the slowest result. It needs about 27 seconds to walk 50 cm (≈ 20 in).

A



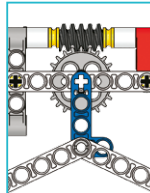
Leg setting B (page 14, step 19) gives the steadiest speed. It needs about 16 seconds to walk 50 cm (≈ 20 in).

B



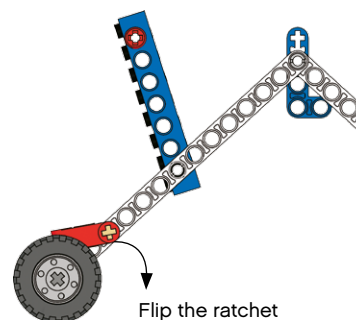
Leg setting C (page 15, step 20) provides the fastest result. It needs about 12 seconds to walk 50 cm (≈ 20 in).

C



Can you explain what the ratchets do?

The front feet cannot grip with the ratchet loose. Without the ratchets the leg movements would force the wheels to roll backward and forward. The ratchet only allows the wheels to roll one way.

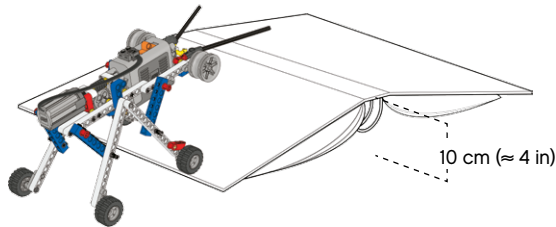


Continue

Which walker is the fastest hill climber?

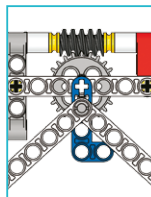
Make a 10 cm (≈ 4 in) hill from a big book or ring binder. Place the walker as shown in the illustration.

First predict which leg settings A, B or C is fastest for climbing over hills? Then test which in fact is the fastest hill climber.



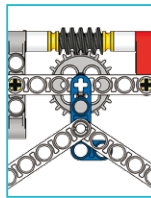
With leg setting A (page 13, step 18) the walker walks slowly, but steadily climbs the hill.

A



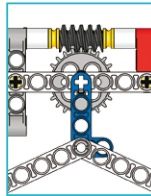
Leg setting B is (page 14, step 19) fast, but more unstable than leg setting A.

B



Leg setting C (page 15, step 20) is the fastest, but very unstable and as such not suited for crossing hills.

C



What else happens?

*The walker rolls down the hill! This is because the ratchets only resist forces in one direction, not the other.
The walker can stand on its antennae.*

Optional: Make the walker move in different ways

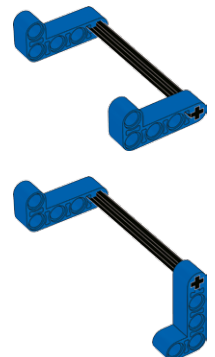
Can you make the walker move in different ways? Try out different settings of the two blue cranks.

Did you know?

A walking robot called Dante 2 is designed to climb down very steep rocky slopes into the gas-covered floors of dangerous volcanoes. It can also rappel down ropes and climb over rocks up to 1 m (≈ 1 yd) high!

Tip:

These crank settings will make the walker move differently.



Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
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b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
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c	that connect scientific ideas, laws, and theories to their own observations.										
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c	while presenting oral or written statements supported by evidence.										
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b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

The Walker

Name(s): _____

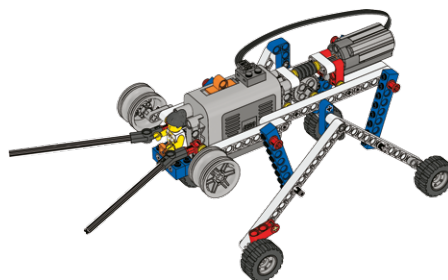
**How can you make a walker that will carry Jack and Jill along the trail?
Let's find out!**



Build the Walker

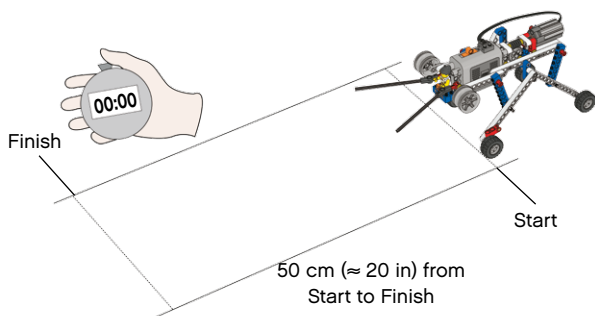
(all of book 13A and book 13B to page 13, step 18)

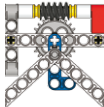
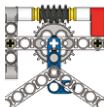
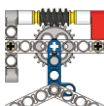
- Make sure the power lead is held clear of all moving parts
- Place it on a smooth surface and start the motor by pushing the battery switch forward
- The legs should move freely



How fast can the walker walk?

- First predict how long it will take the walker to walk 50 cm (≈ 20 in) using leg setting A. Then test your prediction. Next, follow the same procedure for leg settings B and C.
- Test several times to make sure your results are consistent.

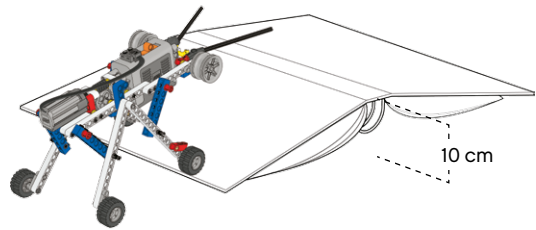


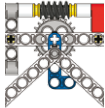
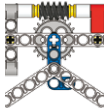
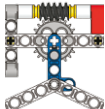
	My Prediction	My Measurements
A 		
B 		
C 		

Can you explain what the ratchets do?

Climbing over hills

- Make a low hill from a big book or ring binder
- Place the walker as shown in the illustration
- First predict which leg settings A, B or C is fastest for climbing over hills? Then test which in fact is the fastest hill climber.



	My Prediction	My Measurements
A 		
B 		
C 		

SlowFastestFast





My Walker

Draw and label your favorite walker design.
Explain how the 3 best parts work.

The Walker

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a walker and investigated three different leg settings to test our walker's speed and climbing ability.				
Structure and Function: Analyze many complex designed structures and systems to determine how they function.	<ul style="list-style-type: none"> We made predictions and measurements for our walker to walk 50 cm using at least two leg settings given on our Student Worksheet. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We completed predictions and measurements for our walker to walk 50 cm using all three leg settings. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We created a testing area for our walker to climb over hills. We completed predictions and measurements using all three leg settings. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We proposed and created at least one new leg design. We compared the speed and climbing ability of our new design with the original walker. <div style="text-align: center;"><input type="checkbox"/></div>
2. Student work related to this Practice: In this project, we explained what the ratchets do for our walkers. We used evidence from our experiments.				
Constructing Explanations: Construct a scientific explanation based on valid and reliable evidence obtained from student's own experiments.	<ul style="list-style-type: none"> We explained what ratchets do. Our explanation was based on at least one specific observation from our experiments. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. Our explanation was based on at least two specific observations from our experiments. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. Observed the walker with and without the ratchets. We used our observations of how the walker moved without a ratchet in our explanation. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We shared with our teacher or classmates new ideas for using the ratchet idea in other LEGO® inventions. <div style="text-align: center;"><input type="checkbox"/></div>
3. Student work related to this Practice: In this project, we labeled our favorite Walker design.				
Obtaining, Evaluating, and Communicating Information: Integrate qualitative and/or quantitative information in written text with visual displays to clarify claims and findings.	<ul style="list-style-type: none"> We labeled one important part of our walker design. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Bronze. We labeled two more important parts of our walker design. We explained how one of the important parts of our walker works. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Silver. We explained how all three important parts of our walker work. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> We met Gold. We created and shared our diagram and explanation with classmates. We revised our work and made it more clear for our classmates to understand. <div style="text-align: center;"><input type="checkbox"/></div>
Notes:				



Dogbot

Technology

- Designing mechanical toys
- Levers and linkages
- Mechanical programming of actions
- Pulleys and gearing
- Using and combining components

Science

- Force and energy
- Friction
- Scientific investigation

Vocabulary

- Cams
- Gears
- Levers
- Linkages
- Pivots
- Sequencing

Other Materials Required

- Crayons
- Decorative materials: wool, foil, card, paper, etc.
- Scissors
- Sticky tape

Connect

Zog is very bored. He dreams of a special friend that is always happy, wide awake and with whom he can share a bone. Jack and Jill have an idea.

**How can we make an exciting friend for Zog to play with?
Let's find out.**

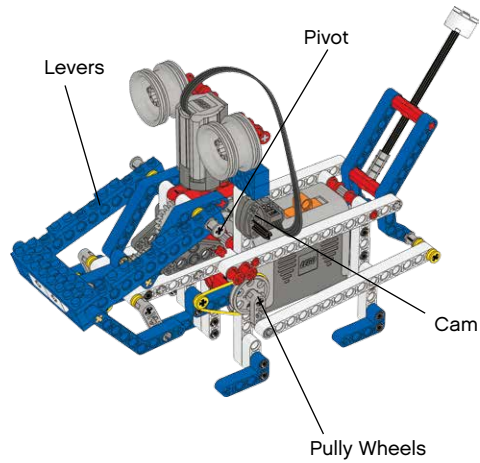


Construct

Build a Dogbot
(all of book 14A and book 14B to page 19, step 27)

There are many moving parts on the dogbot, but only one motor. Turn on the dogbot by pushing backward on the battery switch. If the motor is not turning freely, you need to check several parts of the dogbot:

- The lever on the upper jaw should move up and down
- The cams should rotate freely, moving the eyes attached to the axles up and down
- The lever on the tail should wag up and down



Did you know?

The jaw and tail movements both feature compound levers with several pivots.



Contemplate

Is the dogbot wide awake?

When the dogbot is wide awake its eyes move about a lot!

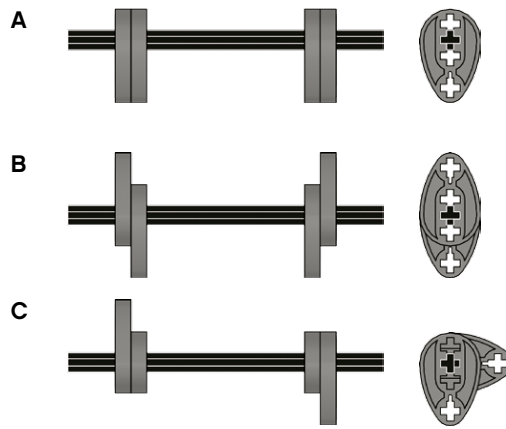
Which cam setting will produce a sleepy, awake and wide awake dogbot?

Predict first which eye action cam setting A will produce. Then test your prediction. Next, follow the same procedure for cam settings B and C.

Cam setting A (page 19, step 27) results in a sleepy dogbot, i.e. only one eye bounce per turn of the cam.

Cam setting B (page 20, step 28) results in a dogbot that is awake, i.e. the eyes bounce twice per turn but at regular intervals.

Cam setting C (page 21, step 29) gives us a dogbot who is wide awake, i.e. the eyes bounce twice per turn but at irregular intervals – one eye is up when the other is down!



Did you know?

Cams work inside car engines, clocks, toys, sewing machines, and locks – in fact anywhere complex, timed actions are required.

How wide can the dogbot's jaws open?

By changing the peg position you can change the extent to which the dogbot can open its jaws.

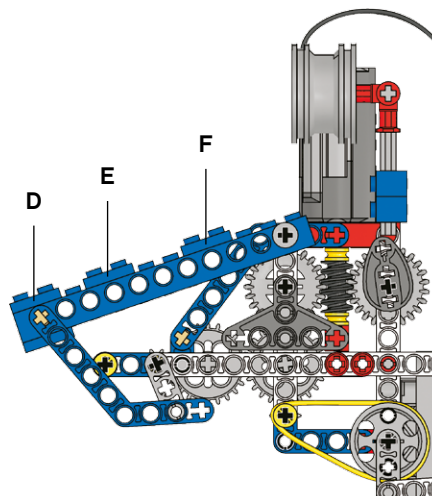
First predict how wide peg position D will make the dogbot's jaws open. Then test your prediction. Next, follow the same procedure for peg positions E and F.

Position D (page 22, step 30) allows the dogbot to open its jaws wide.

Position E (page 23, step 31) means the dogbot can open its jaws even wider.

Position F (page 24, step 32) is the widest possible setting for the dogbot's jaws.

The closer the peg position is to the pivot, the wider the jaws open. The upper jaw is a 3rd class lever.



Did you know?

Your lower jaw is a lever. Feel where the muscle connects to the bone of the lower jaw. Your jaws are 3rd class levers just like the dogbot – just upside down!

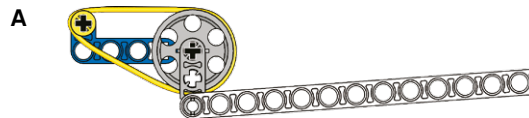
Continue

Can the dogbot be happier?

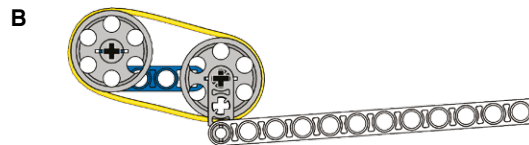
The dogbot wags its tail when it's happy. The faster the wag, the happier it is.

First predict how happy the dogbot is using pulley setting A. Then test your prediction. Next, follow the same procedure with pulley settings B and C.

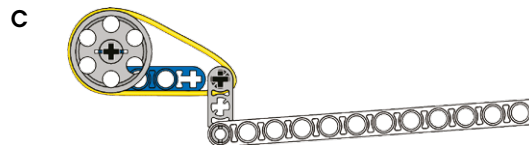
Pulley setting A results in a slow wag, i.e. a happy dogbot.



Pulley setting B results in a faster wag – in fact three times faster than pulley setting A. The dogbot is now even happier.



Pulley setting C gives the fastest wag – three times faster than pulley setting B. This is the happiest the dogbot can be!



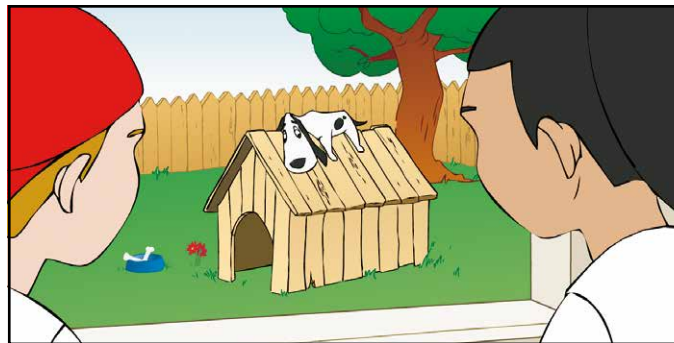
Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

Dogbot

Name(s): _____

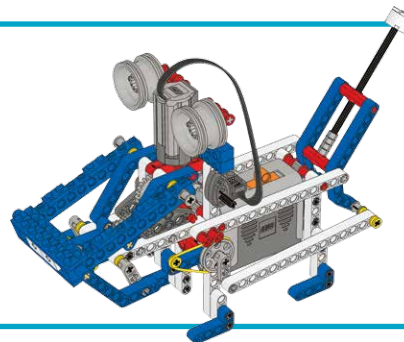
How can we make an exciting friend for Zog to play with?
Let's find out!



Build a Dogbot

(all of book 14A and book 14B to page 19, step 27)

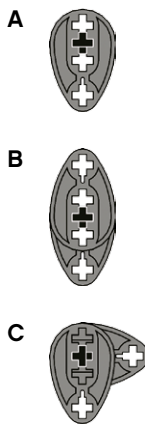
- The lever that forms the upper jaw should move up and down
- The cams should rotate freely moving the eyes attached to the axles up and down
- The lever that acts as a tail should wag up and down



Is the dogbot wide awake?

Which cam setting will produce a sleepy, awake and wide awake dogbot?

- Predict first which eye action cam setting A will produce. Then test your prediction. Next, follow the same procedure for cam settings B and C.



	My Prediction	What happened?
A		
B		
C		

Sleepy

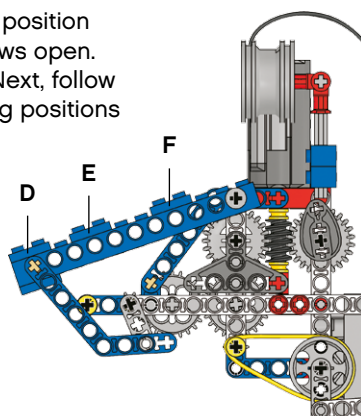
Awake

Wide awake

How wide can the dogbot's

jaws open?

- First predict how wide peg position D will make the dogbot's jaws open. Then test your prediction. Next, follow the same procedure for peg positions E and F.



	My prediction	What happened?
D		
E		
F		

Wide


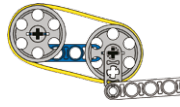

Wider

Widest

How happy is the dogbot?

The dogbot wags its tail when it is happy. The faster the wag, the happier it is.

- First predict how happy the dogbot is using pulley setting A. Then test your prediction. Next, follow the same procedure with pulley settings B and C.

	My Prediction	What happened?
A 		
B 		
C 		



Also try:

- Dress the dogbot up
- Make a cardboard tongue and ears

Happiest

Happier

Happy

My Dogbot

Draw and label your favorite dogbot design.
Explain how the 3 best parts work.





Did you know?

Your lower jaw is a lever. Feel where the muscle connects to the bone of the lower jaw. Your jaws are third class levers just like the dogbot – just upside down!

Dogbot

Name(s): _____

Date: _____

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we drew and labeled our favorite dogbot design. We explained how the three important parts worked. We described the motion patterns we observed in our dogbot.				
Patterns: Observed patterns of forms and events prompt questions about relationships and the factors that influence them.	<ul style="list-style-type: none"> We drew and labeled our dogbot. <div data-bbox="533 921 572 959" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Bronze. We labeled the three important parts of our dogbot. We drew at least one motion pattern for one of the dogbot parts. <div data-bbox="809 921 849 959" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Silver. We explained how the three important parts worked to create a motion pattern in the dogbot. We drew at least two motion patterns for our dogbot's parts. <div data-bbox="1085 921 1125 959" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Gold. We researched and shared with our teacher or classmates the motion patterns in our dogbot that exist in real dogs. <div data-bbox="1362 921 1402 959" style="text-align: center;"> <input type="checkbox"/> </div>
2. Student work related to this Practice: In this project, we built a dogbot and tested different ideas to explore how its eyes, jaws, and tail move.				
Developing and Using Models: Use a model to generate data to test ideas about designed systems.	<ul style="list-style-type: none"> We built a working dogbot. <div data-bbox="533 1295 572 1334" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Bronze. We built three cam designs and tested them on our dogbot's eyes. <div data-bbox="809 1295 849 1334" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Silver. We changed our model to test the jaw motion with three different peg positions. We changed our model to test the tail motion with three different pulley set-ups. <div data-bbox="1085 1295 1125 1334" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Gold. We proposed and tested at least one new design idea for either the eyes, jaw, or tail. <div data-bbox="1362 1295 1402 1334" style="text-align: center;"> <input type="checkbox"/> </div>
3. Student work related to this Practice: In this project, we investigated how the different cam, peg, and pulley settings affected the motion of our dogbot.				
Planning and Carrying Out Investigations: Collect data about the performance of a proposed object under a range of conditions.	<ul style="list-style-type: none"> We completed our predictions and observations for our dogbot eye movement experiment. <div data-bbox="533 1630 572 1668" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Bronze. We completed our predictions and observations for our dogbot's jaw experiment. <div data-bbox="809 1630 849 1668" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Silver. We completed our predictions and observations for our dogbot's tail experiment. <div data-bbox="1085 1630 1125 1668" style="text-align: center;"> <input type="checkbox"/> </div>	<ul style="list-style-type: none"> We met Gold. We completed our predictions and observations for at least one new design idea for either the eyes, jaw, or tail. <div data-bbox="1362 1630 1402 1668" style="text-align: center;"> <input type="checkbox"/> </div>
Notes:				



Uphill Struggle



The Problem

Jack and Jill have made a luxury double-seater cart, but it is very heavy to push up the hill.

Can you design a way to stop the cart from rolling back down the hill when they stop to catch their breath?

Design Brief

Design and make a vehicle that:

- can carry at least 50 g (≈ 1.75 oz) (or approximately 1 weight brick)
- has a safety feature that does not prevent the vehicle from rolling forwards

1. Make a sketch of the idea you designed and made.



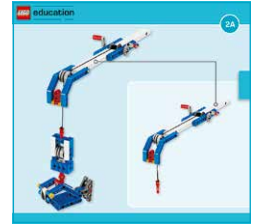
2. Label the three most important parts, explaining how they work.

3. Suggest three improvements.



Need help?

Look at:



Fishing Rod



Freewheeling







Principle models building instructions booklet for wheels and axles



Problem Solving Activity: _____

Name(s): _____

Date: _____

GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
Design Brief: Understand the problem, develop prototypes to solve it, test those prototypes and revise your design to make it better.	<ul style="list-style-type: none"> • Our design met the goals or criteria defined by the activity. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We met Bronze • We tested our prototype multiple times. • We made at least one improvement. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We met Silver • We made at least two improvements. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. <div style="text-align: center;"><input type="checkbox"/></div>
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	<ul style="list-style-type: none"> • We started the activity and have at least one possible solution that looks reasonable. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We brainstormed two to three ideas. • We built a working model to solve the problem. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We brainstormed more than three ideas. • We built an effective model to solve the problem. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We brainstormed many ideas. • We built and tested prototypes for at least two ideas. • We built an original and effective model that solves the problem. <div style="text-align: center;"><input type="checkbox"/></div>
Collaboration: Work is shared effectively and the team encourages and helps each other.	<ul style="list-style-type: none"> • We sometimes worked together well but some team members did more work than others or we needed help from the teacher to resolve some disagreements. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We worked together unusually well, overcoming unexpected obstacles by working together as a team. • We actively helped and supported each other. • We addressed issues that arose with honest, constructive feedback. <div style="text-align: center;"><input type="checkbox"/></div>
Notes: <div style="height: 100px; border: 1px solid black;"></div>				

Uphill Struggle

Objectives

Applying knowledge of:

- Wheels and axles
- Friction
- Ratchets and gears
- Predicting and measuring
- Applying principles of fair testing and product safety

Other Materials Required

- A meter rule or measuring tape
- A plank to make a sloping hill
- Card and tape to make a runoff ramp at the bottom of the hill
- A desk fan to provide the energy for wind-assisted carts
- Optional: playdough for making test pilots

Fair Testing and Fun

- Can the cart carry the weight of at least one weight brick?
Test to see, then add more weight. What are the criteria for success?
The cart should not break and the load should not rub against the wheels, etc.
- Does it roll freely?
Set the hill at any slope angle you like, (e.g. 30 cm [\approx 12 in] high at one end of a 1 meter [\approx 1 yard] plank) and run the cart forwards down it. The further it rolls along the floor the better.
- Does the autostop feature work?
Turn the cart around without touching anything on board so it faces backwards down the hill. Let go! Does it stay still? Keep increasing the steepness until the cart slips. The steeper you can go before it slips, the better.
- How safe and comfortable is your luxury cart?
Make two play dough riders with very smooth skin. Place them gently on the cart in whatever seats are supplied. Let the cart run down the hill until it stops. Now check the riders for bumps, cuts, and bruises – the less, the better.
How will they survive bumping over an all-terrain course?
Would your cart be a good ambulance?

Extra Challenges

- Harness wind energy to help push the cart uphill. Make sure that the autostop will stop it rolling down the hill again if the wind stops.
- All Terrain Cart! Can you find a way to make the cart climb over rulers and maybe even pencils that are put in its way on the hillside?
Tip: Create a means of storing things on board the cart.

◀ **Need help?**
Look at:



Fishing Rod

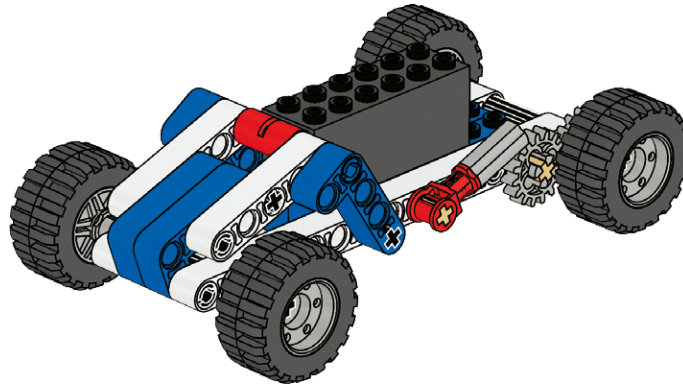


Freewheeling



Principle models building instructions booklet for wheels and axles

Suggested Model Solution



Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
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a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
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Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
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d	that apply scientific ideas, laws, and theories.										
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a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
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Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

The Magic Lock



The Problem

Jack wants to keep his secret treasure locked away in a box. But he knows Jill can undo almost any lock and she is always so curious and wants to know his secrets!

Can you design a secret way to 'lock' a box that does not use a key?

Design Brief

Design and make a box:

- with a secret or hidden lock or catch
- that can be 'locked' and 'unlocked' in a very simple way

1. Make a sketch of the idea you designed and made.



2. Label the three most important parts, explaining how they work.

3. Suggest three improvements.



Need help?

Look at:







Principle models building
instructions booklet for
levers



Problem Solving Activity: _____

Name(s): _____

Date: _____

GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
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The Magic Lock

Objectives

Applying knowledge of:

- Levers, structures and hinges
- Observing and investigating
- Applying principles of fair testing and product reliability

Need help?

Look at:



Principle models building instructions booklet for levers

Other Materials Required

- Cardboard
- Markers
- Scissors

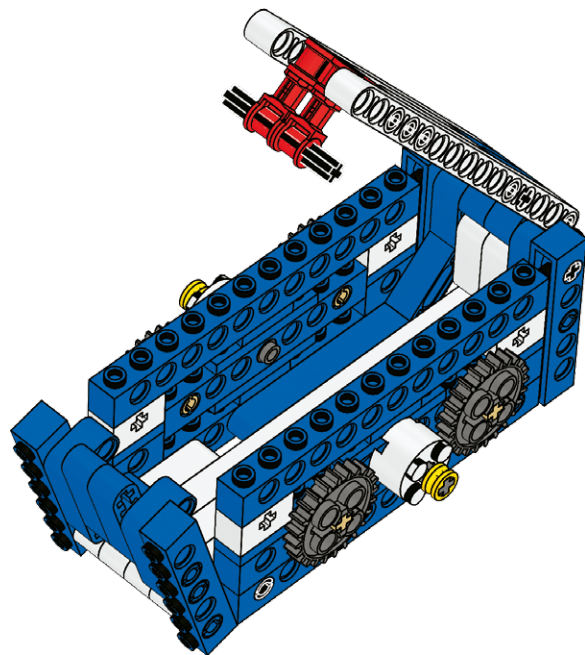
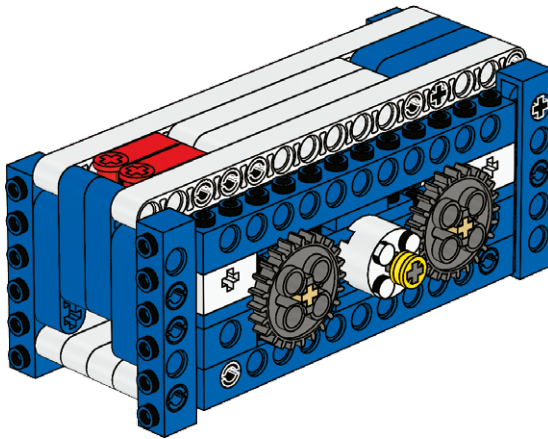
Fair Testing and Fun

- Does the box stay shut when it is 'locked'?
Lock the box. Now try and see if it opens by pushing it or shaking it a little. Remember it is still just a prototype!
- Does it open properly?
Test to find out. The easier it opens, the better.
- How reliable is it?
Lock, unlock and open it three times in a row. Is it still working OK? Keep going! The more times it can be locked and unlocked, the more reliable it is.
- How secret is it?
Ask volunteers from another group to step forward and try and point out how you open the box. You may want to time it. The less people can guess how and where to open the box, the better!

Extra Challenges

- Design and make different box sides so that the content is totally hidden.
- Using cardboard and markers, personalise the sides of your box.

Suggested Model Solution



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a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

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b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
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Notes:											

Stamping Letters



The Problem

It is too windy to play outside so Jill is helping out in the post office stamping letters. Her arm is getting sore from stamping, she is very tired and she wishes there was a way of using the wind to help her!

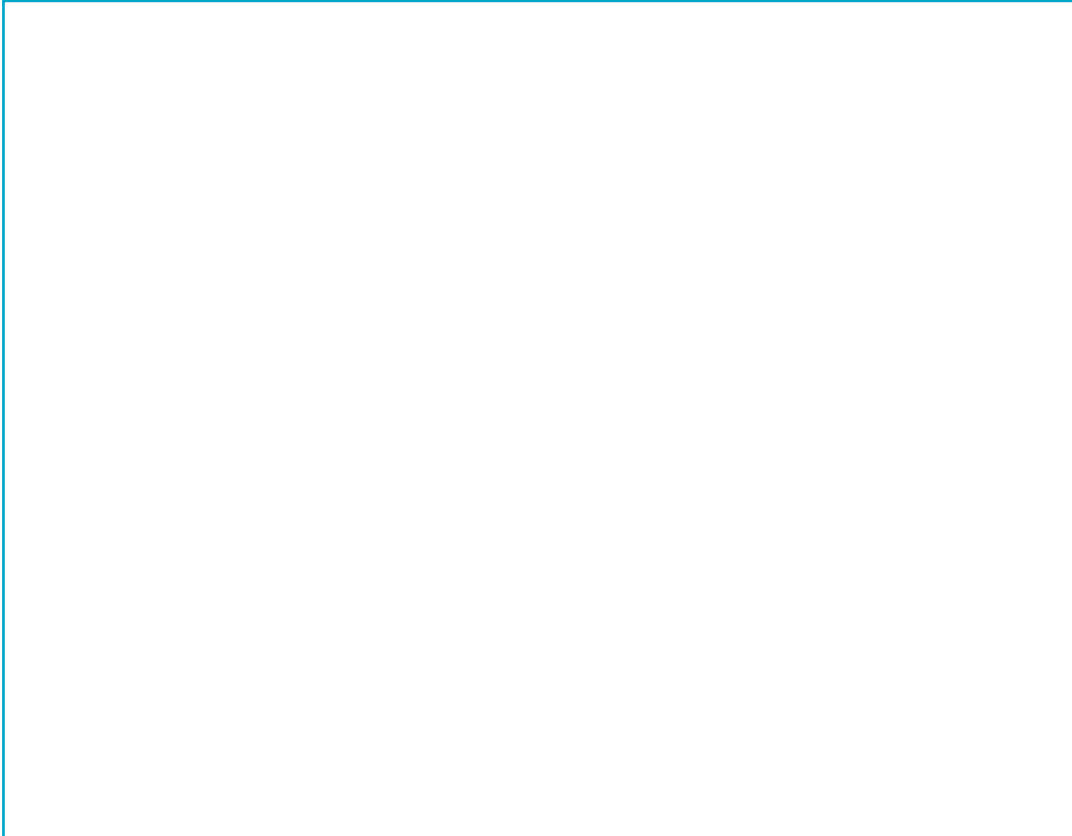
Can you think of a way to help her out?

Design Brief

Design and make a wind-powered stamping machine:

- it must make a mark on thin paper
- the more times it stamps the mark within one minute, the better
- it must be powered by the wind from a desk fan placed approximately one meter (\approx one yard) away

1. Make a sketch of the idea you designed and made.



2. Label the three most important parts, explaining how they work.

3. Suggest three improvements.



Need help?

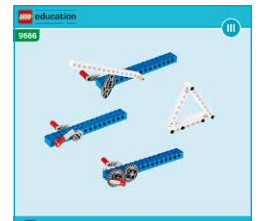
Look at



The Hammer



Windmill







Principle models building instructions booklet for levers and gears



Problem Solving Activity: _____

Name(s): _____

Date: _____

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Stamping Letters

Objectives

Applying knowledge of:

- Renewable energy
- Levers
- Cams
- Gears
- Observing, improving, and measuring
- Applying principles of fair testing and product safety

Other Materials Required

- Paper
- Scissors
- Tape

Fair Testing and Fun

- Does the stamper mechanism work in the wind?
*Start the fan one meter away from the stamper and see if the mechanism moves.
You don't need to actually test with paper yet.*
- Does it actually stamp paper?
*Cut up several pieces of paper to be the letters. Stamp half of them with the machine.
Give all the pieces to someone else. Can he or she tell you which ones are stamped and which ones are not?*
- How productive is it?
Have a stamping race. With the stamper one meter (≈ one yard) from the fan, how many letters can your model stamp in one minute? The more the better.
- How energy efficient is it?
*How far can you move the stamper away from the wind and still stamp letters?
The further away it works, the more energy efficient it is.*
- How safe is it?
Check to see if you can get your finger stamped by mistake. The safest stamper will be easy to use but hard to hurt yourself on.

Extra Challenges

- Make a special conveyor system to carry letters under the stamper.
- Make a real ink transfer stamp out of an old eraser with a ballpoint ink message on it.
Can you write in mirror writing so you can read the message? How many times will it stamp before you need to re-ink it?
- Design and make a system that will tell you automatically how many times the stamper has stamped.

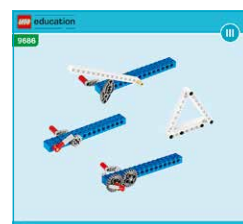
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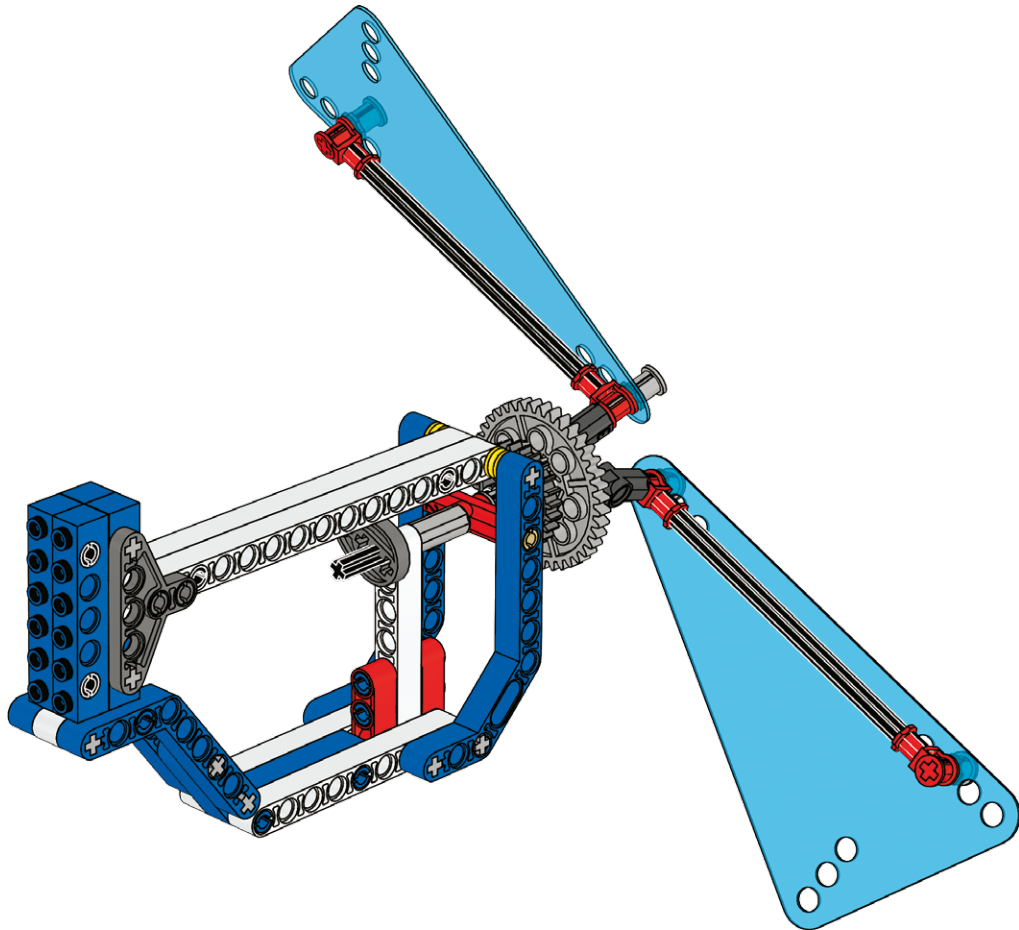
The Hammer



Windmill



Principle models building instructions booklet for levers and gears

Suggested Model Solution

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Beaten



The Problem

Granny is scared of electric mixers, but she gets tired when she uses a whisk to beat eggs for pancakes or cake mixes. Is there a better way for Granny to beat eggs?

Can you help Jack and Jill come up with a solution?

Design Brief

Design and make a hand mixer:

- that is easy to hold and use
- that really works
- with beaters that spin much faster than the handle you turn
- in which the beaters are at least 10 cm (\approx 4 in) away from the nearest part of your hand

1. Make a sketch of the idea you designed and made.



2. Label the three most important parts, explaining how they work.

3. Suggest three improvements.



Need help?

Look at:



Sweeper



Flywheeler







Principle models building instructions booklet for gears and pulleys



Problem Solving Activity: _____

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Date: _____

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Beaten

Objectives

Applying knowledge of:

- Gears and/or pulleys
- Energy efficiency
- Evaluating efficiency
- Applying principles of fair testing and product safety

Other Materials Required

- Ruler
- Stopwatch
- Cups or small bowls half full of warm water and a few drops of washing-up liquid
- Trays to stop spills
- Volunteers from another group to test the mixers
- Towels to dry up

Fair Testing and Fun

- Safety first: How close are your hands to the beaters?
Hold the mixer and turn the handle. Measure the closest distance from hand to beater with a ruler. It should be at least 10 cm (≈ 4 in).
- How fast do the beaters turn?
Turn the handle once. Count how many turns of the beaters – the more the better. Your beaters should be able to turn at least five times faster than the handle.
- How well does the mixer work? How efficient is it?
Each mixer must mix the same amount of soapy water for the same time to constitute a fair test. Place your test volunteers in front of the test bowls (with NO BUBBLES on top). Start the stop watch and start the mixers. Stop after one minute. Quickly measure the depth of bubbles – the more the better.
- How comfortable, easy, and safe to use is it?
*Check the volunteer's hands. Count the marks left from gripping the mixer – the more there are, the more uncomfortable it is to use. Ask them to rate how easy it was to use (1 for hard; 5 for very easy). How many accidents did they have – the less the better!
*The most efficient mixer will make more bubbles, more quickly with greater comfort and ease of use.**

Extra Challenges

- Make a super-safe mixer with a drive mechanism that slips if you get a finger or a tie stuck in the beaters.
- Turn it into a dough mixer! The beaters should turn as slowly as possible compared to the handle. Try it for real with flour and water.
- Can you adapt your mixer to become a washing machine? Make a top-loading washing machine in a cup. Use tiny squares of cloth with sauce as the test clothes. As you turn the handle one way, the beaters should rotate back and forth.

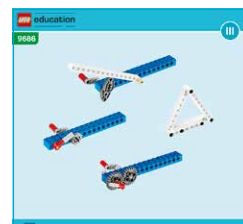
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Sweeper

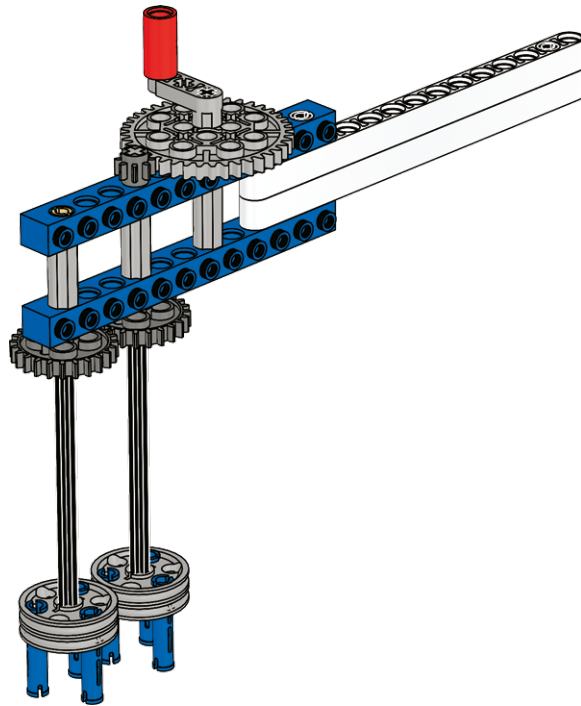


Flywheeler



Principle models building instructions booklet for gears and pulleys

Suggested Model Solution



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The Lifter



The Problem

Jack, Jill and Zog have a wonderful tree house, but it's hard work climbing up and down. It's even more difficult if they want to stock up with supplies.

Can you help Jack and Jill come up with a solution?

Design Brief

Design and make a motorized lift that can carry:

- at least 50 g (or approximately 1 weight brick)
- an object at least 20 cm into the air

1. Make a sketch of the idea you designed and made.



2. Label the three most important parts, explaining how they work.

3. Suggest three improvements.



Need help?

Look at:



Power Car



Fishing Rod







Principle models building instructions booklet for gears and levers



Problem Solving Activity: _____

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Notes: <div style="height: 100px; border: 1px solid black;"></div>				

The Lifter

Objectives

Applying knowledge of:

- Pulleys
- Gears
- Forces
- Applying principles of fair testing and product safety

Other Materials Required

- A ruler

Fair Testing and Fun

- Does it lift smoothly and at a safe speed?
The smoother it lifts, the better. If the lift is too fast, it is not safe.
- Without supporting or stopping it from tilting, test how much the lift can carry.
The more it can carry without tilting, the better.
- Load the lift and test how much it can carry before the motor stalls.
The more, the better.

Extra Challenges

- Construct a mechanism that makes a sound when the supplies have reached the tree house.

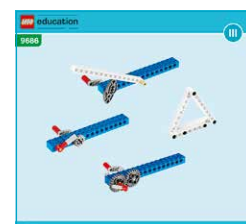
◀ **Need help?**
Look at:



Power Car

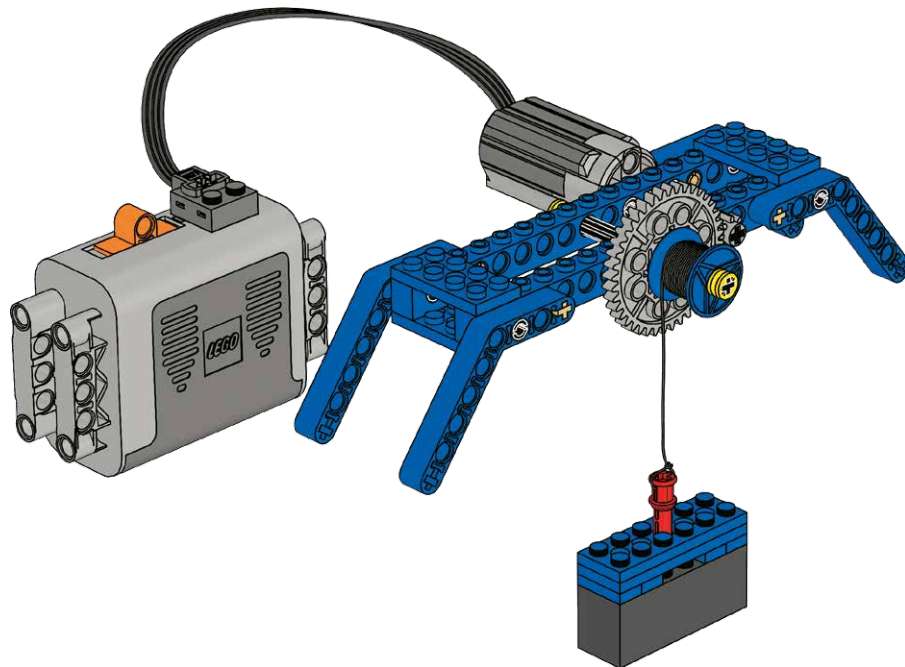


Fishing Rod



Principle models building instructions booklet for gears and levers

Suggested Model Solution



Observation Checklist Part 1		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 1: I observed students asking questions:											
a	to seek more information.										
b	to seek evidence to support a claim.										
c	to challenge a claim or interpretation of data.										
d	to identify and understand independent and dependent variables.										
e	that can be investigated in this class.										
Practice 2: I observed students developing and/or using a model:											
a	to explore its limitations.										
b	to explore what happens when parts of the model are changed.										
c	to show the relationship between variables.										
d	to make predictions.										
e	to generate data about what they are designing or investigating.										
Practice 3: I observed students planning and carrying out investigations:											
a	that included independent and dependent variables and controls.										
b	that included appropriate measurement and recording tools.										
c	that tested the accuracy of various methods for collecting data.										
d	to collect data to answer a scientific question or test a design solution.										
e	to test the performance of a design under a range of conditions.										
Practice 4: I observed students analyzing and interpreting data:											
a	by constructing graphs.										
b	to identify linear and non-linear relationships.										
c	to distinguish between cause and effect vs. correlational relationships.										
d	by using statistics and probability such as mean and percentage.										
e	to determine similarities and differences in findings.										
f	to determine a way to optimize their solution to a design problem.										
Notes:											

Observation Checklist Part 2		Name(s)									
Science and Engineering Practices Grade 6-8 Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.											
Practice 5: I observed students using mathematics and computational thinking:											
a	by including mathematical representations in their explanations and design solutions.										
b	by using an algorithm to solve a problem.										
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.										
Practice 6: I observed students constructing explanations and design solutions:											
a	that included quantitative and qualitative relationships.										
b	that are based on scientific ideas, laws, and theories.										
c	that connect scientific ideas, laws, and theories to their own observations.										
d	that apply scientific ideas, laws, and theories.										
e	to help optimize design ideas while making trade-offs and revisions.										
Practice 7: I observed students engaging in arguments from evidence:											
a	that compare and critique two arguments on the same topic.										
b	while respectfully providing and receiving critiques using appropriate evidence.										
c	while presenting oral or written statements supported by evidence.										
d	while evaluating different design solutions based on agreed-upon criteria and constraints.										
Practice 8: I observed students evaluating and communicating information:											
a	when they read scientific text adapted for the classroom.										
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.										
c	when they created presentations about their investigations and/or design solutions.										
Notes:											

The Bat



The problem

Jack, Jill and Zog are at school performing their own play called Ghost of the Bat Cave. Zog doesn't want to be the bat; he would much rather be a ghost or a dangerous dragon.

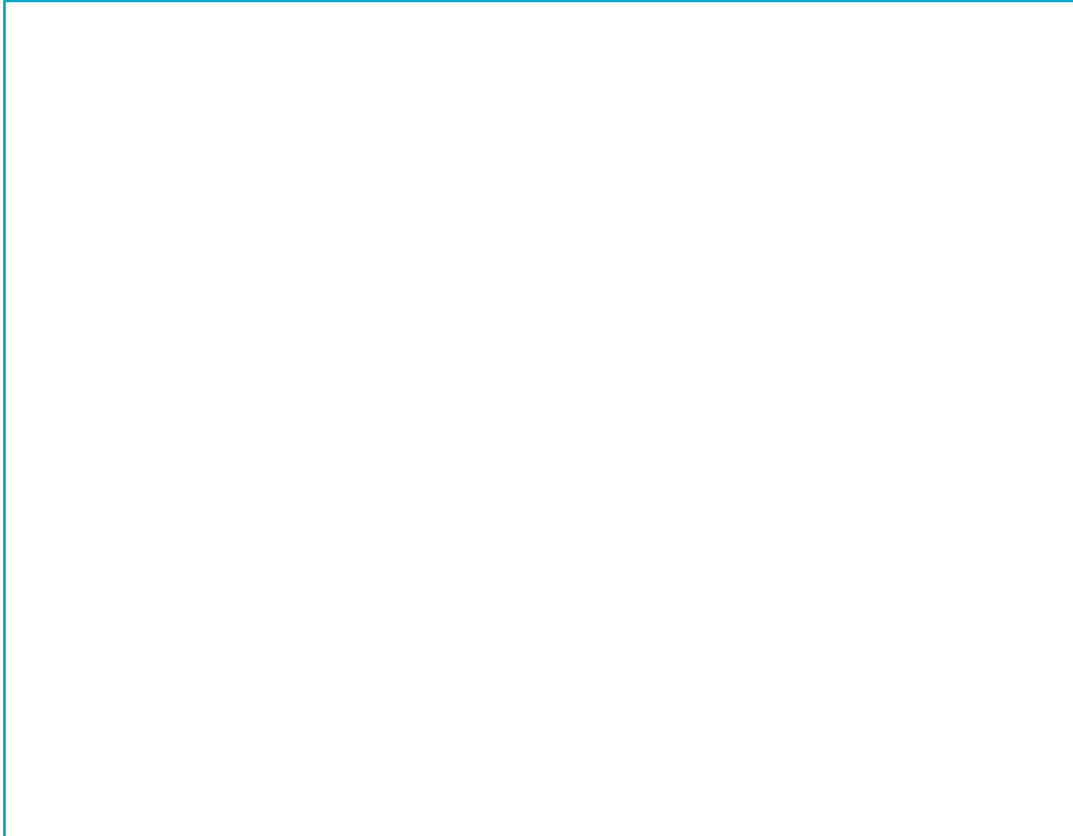
Can you help Jack and Jill design a bat for their play?

Design Brief

Design and make a motorized bat that:

- can flap its wings
- has eyes
- is easy to hold

1. Make a sketch of the idea you designed and made.



2. Label the three most important parts, explaining how they work.

3. Suggest three improvements.



Need help?

Look at:



The Walker







Principle models building instructions booklet for gears and levers



Problem Solving Activity: _____

Name(s): _____

Date: _____

GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
Design Brief: Understand the problem, develop prototypes to solve it, test those prototypes and revise your design to make it better.	<ul style="list-style-type: none"> • Our design met the goals or criteria defined by the activity. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We met Bronze • We tested our prototype multiple times. • We made at least one improvement. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We met Silver • We made at least two improvements. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. <div style="text-align: center;"><input type="checkbox"/></div>
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	<ul style="list-style-type: none"> • We started the activity and have at least one possible solution that looks reasonable. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We brainstormed two to three ideas. • We built a working model to solve the problem. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We brainstormed more than three ideas. • We built an effective model to solve the problem. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We brainstormed many ideas. • We built and tested prototypes for at least two ideas. • We built an original and effective model that solves the problem. <div style="text-align: center;"><input type="checkbox"/></div>
Collaboration: Work is shared effectively and the team encourages and helps each other.	<ul style="list-style-type: none"> • We sometimes worked together well but some team members did more work than others or we needed help from the teacher to resolve some disagreements. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose. <div style="text-align: center;"><input type="checkbox"/></div>	<ul style="list-style-type: none"> • We worked together unusually well, overcoming unexpected obstacles by working together as a team. • We actively helped and supported each other. • We addressed issues that arose with honest, constructive feedback. <div style="text-align: center;"><input type="checkbox"/></div>
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The Bat

Objectives

Applying knowledge of:

- Levers and gears
- Cams, cranks and timing actions
- Applying principles of fair testing and product reliability

Other Materials Required

- A ruler
- Stopwatch or timer
- Decorative materials: wool, foil, card, paper, etc.
- Sticky tape

Fair Testing and Fun

- How wide is the bat's wingspan?
Measure with a ruler. The wider, the better.
- How many times per 15 seconds does the bat flap its wings?
The more flaps per 15 seconds, the better.
- Can the bat flap at different intervals?
Have the children show how this is done if possible?

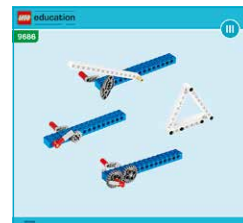
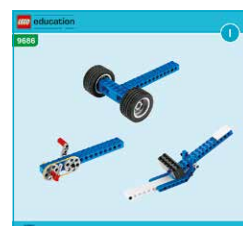
Extra Challenges

- Add another movement to the bat – it could be eye or ear movement.
- Decorate the bat to make it look as realistic as possible.

◀ **Need help?**
Look at:

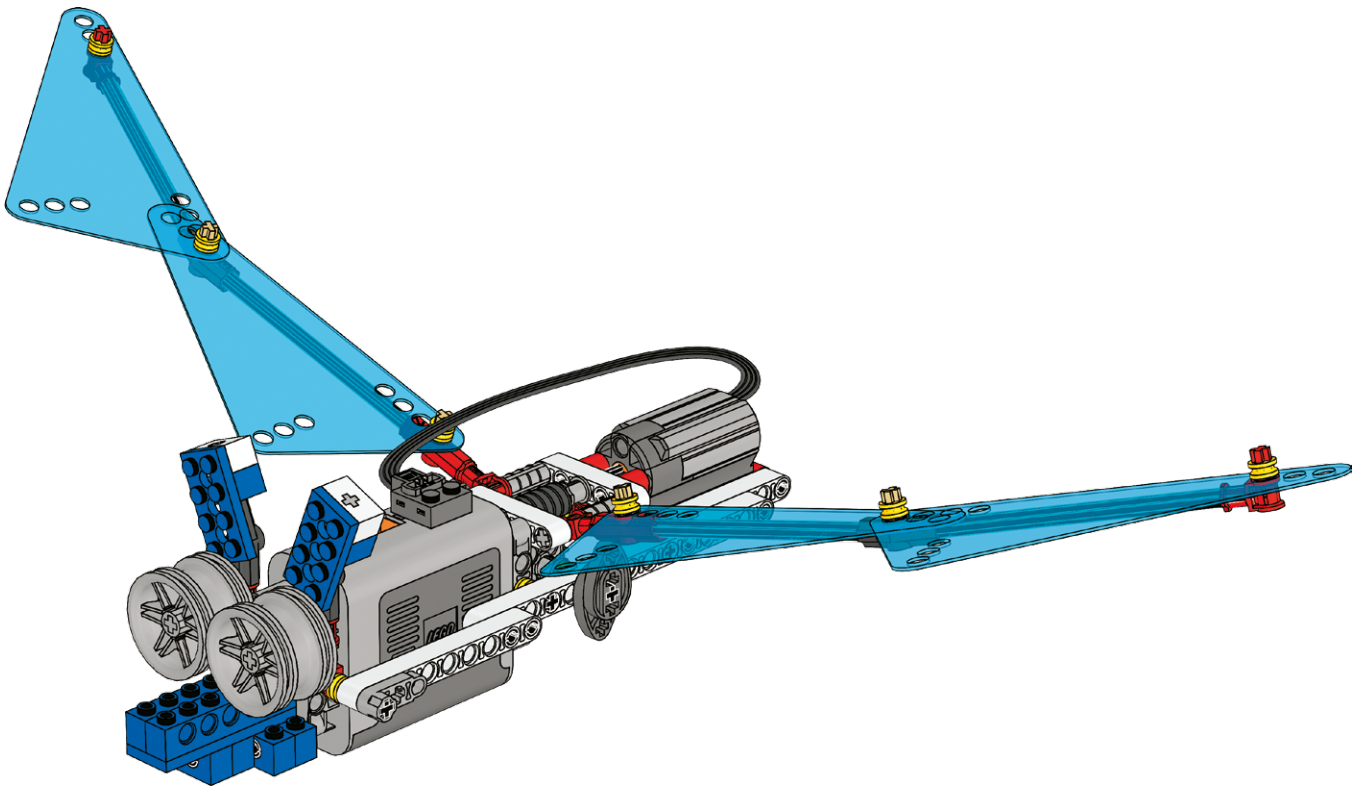


The Walker



Principle models building instructions booklet for gears and levers

Suggested Model Solution



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Glossary

We have tried to make the glossary as understandable and practical as possible without resorting to difficult equations and long explanations.

A	Acceleration	The rate at which speed increases. If a car is accelerating it is moving faster.
	Advantage	The ratio of the output force to the input force of a machine. Often a measure of how useful it is to us. This is sometimes called mechanical advantage.
	Air resistance	The force that air creates by pushing back on a vehicle or object that is trying to push through it. A streamlined shape creates less air resistance.
	Amplify	To make larger. For instance a lever can amplify the force from your arm.
	Anvil	A very heavy, flat, block of steel or iron on which heated metals are shaped by hammering.
	Axle	A rod through the center of a wheel, or through different parts of a cam. It transmits force, via a transmission device, from an engine to the wheel in a car or from your arm via the wheel to the axle if you are winding up a bucket on a rope.
B	Balanced force	An object is balanced and does not move when all the forces acting on it are equal and opposite.
	Bearing	Part of a machine which supports moving parts. Most of the holes in LEGO® elements can work as bearings for LEGO axles. The special plastic is very low friction, so axles turn easily.
	Belt	A continuous band stretched around two pulley wheels so one can turn the other. It is usually designed to slip if the follower pulley suddenly stops turning.
	Block and tackle	An arrangement or system of pulleys and line so that the ability to lift a very heavy object requires far less force
C	Calibrate	To set up and mark out the units on a scale for a measuring instrument. We can use known values like brass weights to mark a letter balance scale in grams or a stopwatch to mark our new timer in seconds. This is called calibrating.
	Cams	A non-circular wheel that rotates and moves a follower. It converts the rotary movement of the cam into reciprocating or oscillating the movement of the follower. Sometimes a circular wheel mounted off-center on a shaft is used as a cam.
	Compression forces	Forces in a structure that push in opposite directions, trying to crush the structure.

Control mechanism A mechanism that regulates an action automatically. A ratchet stops an axle from turning the wrong way; an escapement stops a clock from running too fast.

Counter balance A force often provided by the weight of an object you use to reduce or remove the effects of another force. A crane uses a large concrete block on the short arm of its jib to counter the unbalancing effect of the load of the other longer arm.

Crank An arm or handle connected to a shaft (or axle) at right angles enabling the shaft to be easily turned.

D

Driven gear See Follower.

Driver The part of a machine, usually a gear, pulley, lever, crank or axle, where the force first comes into the machine.

E

Efficiency A measure of how much of the force that goes into a machine comes out as useful work. Friction often wastes a lot of energy, reducing the efficiency of a machine.

Effort The force or amount of force that you or something else puts into a machine.

Energy The capacity to do work.

Escapement A control mechanism in a timer that stops energy from escaping too quickly; for example, a spring or falling weight. Usually it ticks!

F

Fair testing Measuring the performance of a machine by comparing its performance under different conditions.

Flywheel A wheel that stores moving energy when it is spinning and releases it slowly. The heavier, wider, and faster the wheel, the more energy it stores.

Follower Usually a gear, pulley, or lever driven by another one. It can also be a lever driven by a cam.

Force A push or a pull.

Friction The resistance met when one surface is sliding over another, for example, when an axle is turning in a hole or when you rub your hands together.

Fulcrum See Pivot.

G

Gear A toothed wheel or cog. The teeth of gears mesh together to transmit movement. Often called a spur gear.

Gear, crown Has teeth that stick out on one side looking like a crown. Mesh it with a regular spur gear to turn the angle of motion through 90°.

Gear, rack A flat gear with the teeth equally spaced on a straight line that converts rotational motion into linear motion when a spur gear is meshed against it.

Gear, bevel	Gear with teeth that are cut at a 45° angle. When two bevel gears mesh, they change the angle of their axles and movement through 90°.
Gear, worm	A gear with one spiral tooth resembling a screw. Mesh it with a pinion to deliver large forces very slowly.
Gearing down	A small driver turns a larger follower and amplifies the force from the effort, but the follower turns more slowly.
Gearing up	A large driver turns a smaller follower and reduces the force from the effort, but the follower turns more quickly.
Gearing, compound	A combination of gears and axles where at least one axle has two gears of different sizes. Compound gearing results in very big changes to the speed or force of the output compared to the input.
Grip	The grip between two surfaces depends on the amount of friction between them. Tires grip dry road surfaces better than wet road surfaces.
I	
Idler	A gear or pulley that is turned by a driver and then just turns another follower. It does not transform the forces in the machine.
Inclined plane	A slanted surface or ramp generally used to raise an object with less effort than is needed to lift it directly. A cam is a special sort of continuous inclined plane.
J	
Jib	A triangular sail at the very front of a sailing boat.
K	
Kinetic energy	The energy of an object that is related to its speed. The faster it travels, the more kinetic energy it has. See also potential energy.
L	
Lever	A bar that pivots about a fixed point when an effort is applied to it.
Lever, first class	The pivot is between the effort and the load. A long effort arm and short load arm amplifies the force at the load arm, for example, when prying the lid off a can of paint.
Lever, second class	The load is between the effort and the pivot. This lever amplifies the force from the effort to make lifting the load easier, for example, in a wheelbarrow.
Lever, third class	The effort is between the load and the pivot. This lever amplifies the speed and distance the load moves compared to the effort.
Linkages	A mechanical linkage carries movement and forces through a series of rods or beams connected by moving pivot points. Locking pliers, a scissors lift, a sewing machine, and a garage door lock all contain linkages.
Load	Any force a structure is calculated to oppose, such as a weight or mass. It can also refer to the amount of resistance placed on a machine.

M	Machine	A device that makes work either easier or faster to do. It usually contains mechanisms.
	Mass	Mass is the quantity of matter in an object. On Earth, gravitational force pulling your matter makes you weigh say 70 kg. In orbit, you feel weightless – but you still have a mass of 70 kg. Mass is often confused with weight.
	Mesh	The way gears contact each other by fitting together
	Member	The name given to individual parts of a structure, for example, a door frame is made from two upright members and one cross member.
	Mechanism	A simple arrangement of components that transforms the size or direction of a force, and the speed of its output. For example, a lever or two gears meshing.
	Momentum	The product of the velocity and mass of an object: velocity not speed because direction is important; mass is used, not weight because momentum isn't dependent on gravity.
N	Net weight	The weight of a substance after the weight of its container has been taken away.
O	Oscillating	Moving back and forth in steady pattern
P	Pawl and ratchet	An arrangement of a block or wedge (pawl) and a gear wheel (ratchet) that lets the gear turn in one direction only.
	Pendulum	A weight hung from a fixed point so that it can swing freely back and forth under the influence of gravity.
	Period of swing	The time it takes for a pendulum to complete one swing. For our pendulum, lowering the weight lengthens the pendulum and lengthens the time or period of swing and vice versa.
	Pinion	Another name for a gear that meshes with a gear rack or worm gear.
	Pitch	The distance moved by a screw when the screw is turned through one complete turn (360°).
	Pivot	The point around which something turns or rotates, such as the pivot of a lever.
	Potential energy	The energy of an object that is related to its position. The higher up it is, the more potential energy it has. See also Kinetic energy.
	Power	The rate at which a machine does work (work divided by time). See also Work.
	Pulley	A wheel with a grooved rim used with a belt, chain or rope.
	Pulley, fixed	Changes the direction of the applied force. A fixed pulley does not move with the load.

Pulley block One or more pulleys in a movable frame with ropes or (block and tackle) chains running around them to one or more fixed pulleys. The pulley block moves with the load and reduces the applied force needed to lift the load.

Pulley, movable Changes the amount of applied force needed to lift the load. A movable pulley moves with the load.

R

Rack (gear rack) A specialized gear in the shape of a flat bar with teeth.

Reciprocating Moving back and forth over and over again

Renewable energy Energy from a renewable source such as sunlight, wind or flowing water.

Resetting Turning a pointer on a scale back to zero again.

Rigid A rigid material does not easily stretch or bend and does not deform under load.

Rotary movement Motion in a circle like a wheel moving around an axle

RPM Revolutions or turns per minute. This is usually the measure of speed of a motor. The LEGO® motor turns at about 400 rpm unloaded (when it is not driving a machine).

S

Sequencing Setting up actions to happen in the right order and at the correct time intervals. Cams are often used for this purpose.

Sheave A pulley wheel with a grooved rim. The groove is used to hold a rope, belt, or cable so that it does not slip off the wheel.

Slip A belt or rope slipping, usually on a pulley wheel as a safety feature.

Speed Rate or measure of motion; To calculate the speed of a vehicle, we divide the distance travelled by the time taken, 45 mph.

Strut A member of a structure that is in compression. Struts prevent parts of structures from moving towards each other.

T

Tare Adjust the weight on a scale so that the weight of the container is removed and only the weight of the product is measured.

Tensile forces Forces in a structure that pull in opposite directions trying to stretch the structure.

Tie A member of a structure that is in tension. Ties prevent parts of structures from moving apart, in other words, they 'tie' the members together.

Torque The turning force coming from an axle.

Transmission A system of gears or pulleys with an input and one or more outputs. A gearbox contains a transmission, and so does a clock.

U

Unbalanced force A force that is not opposed by an equal and opposite force. An object feeling an unbalanced force must begin to move in some way.

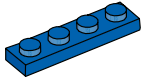
V	Velocity	The rate of at which an object changes position; for example, velocity is given in a rate and direction 45 mph west.
W	Weight	How much an object weighs based on the force of gravity pulling on the object; an object can have different weights based on location such as on Earth or Moon.
	Wind resistance	The force that air (wind) creates by pushing back on a vehicle or object that is trying to push through it. A streamlined shape creates less air (wind) resistance.
	Work	Product of the force needed to move an object by the distance it is moved (force x distance). See also Power.



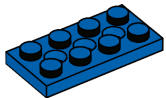
LEGO® Element Survey



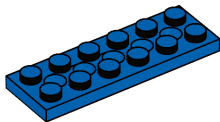
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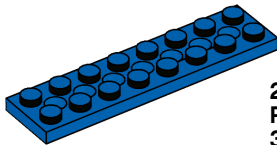
4x
Plate, 1x4, blue
371023



6x
Plate with holes, 2x4, blue
370923



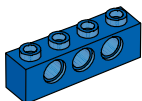
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Plate with holes, 2x6, blue
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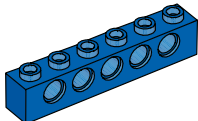
2x
Plate with holes, 2x8, blue
373823



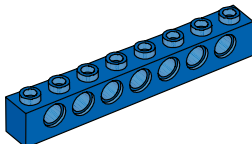
4x
Studded beam, 1x2, blue
370023



4x
Studded beam, 1x4, blue
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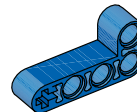
4x
Studded beam, 1x6, blue
389423



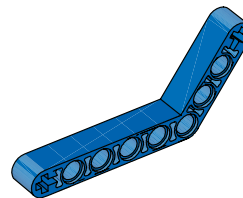
4x
Studded beam, 1x8, blue
370223



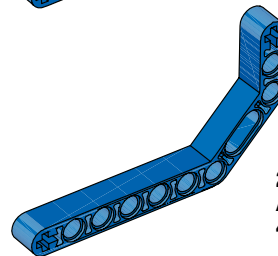
10x
Connector peg with friction,
3-module, blue
4514553



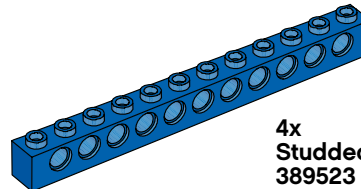
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Angular beam, 4x2-module, blue
4168114



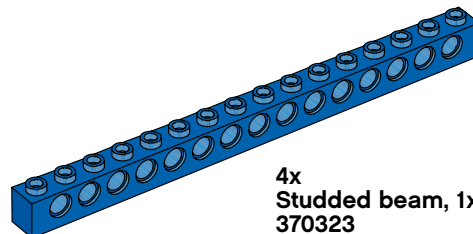
4x
Angular beam, 4x6-module, blue
4182884




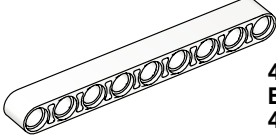

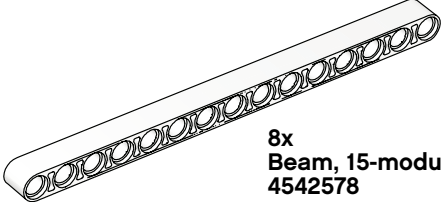



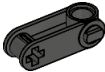














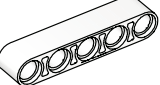
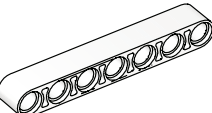
2x
Angular beam, 3x7-module, blue
4112000



4x
Studded beam, 1x12, blue
389523

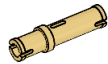


4x
Studded beam, 1x16, blue
370323

	14x Axle, 2-module, red 4142865		4x Beam, 9-module, white 4156341
	14x Connector peg with bushing, red 4140806		8x Beam, 15-module, white 4542578
	4x Angular block, 2 (180°), red 4234429		
	10x Angular block with crosshole, red 4118897		
	4x Cross block, 3-module, red 4175442		2x Steering arm, black 4114670
	2x Tube, 2-module, red 4526984		2x Bearing for steering arm, black 4114671
	4x Studded beam, 1x2 with crosshole, white 4233486		4x Angular block, 1 (0°), dark grey 4210658
	2x Brick, 2x4, white 300101		4x Angular block, 3 (157,5°), black 4107082
	2x Brick, 2x2 round, white 614301		28x Connector peg with friction, black 4121715
	4x Roof brick, 1x2/45°, white 4121932		4x Tyre, 30,4x4, black 281526
	2x Tile, 1x4, white 243101		4x Tyre, 30,4x14, black 4140670
	2x Beam, 3-module, white 4208160		4x Tyre, 43,2x22, black 4184286
	2x Beam, 5-module, white 4249021		
	2x Beam, 7-module, white 4495927		



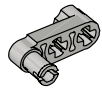
12x
Connector peg with axle, beige
4186017



4x
Connector peg, 3-module, beige
4514554



16x
Bushing, 1/2-module, yellow
4239601



4x
Connector peg, handle, grey
4211688



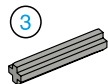
8x
Connector peg, grey
4211807



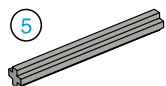
16x
Bushing, grey
4211622



8x
Axle extender, 2-module, grey
4512360



8x
Axle, 3-module, grey
4211815



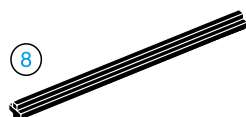
4x
Axle, 5-module, grey
4211639



8x
Axle, 4-module, black
370526

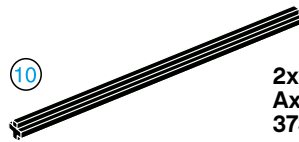


2x
Axle, 6-module, black
370626



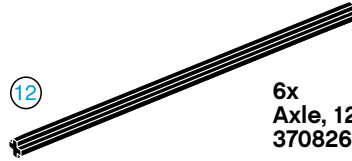
2x
Axle, 8-module, black
370726

10



2x
Axle, 10-module, black
373726

12



6x
Axle, 12-module, black
370826



1x
Minifigure, ponytail wig, black
609326



1x
Minifigure, cap, red
448521



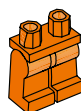
2x
Minifigure, head, yellow
9336



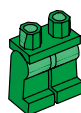
1x
Minifigure, body, white with surfer
4275606




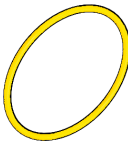


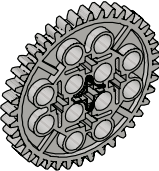

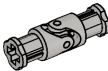







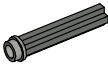


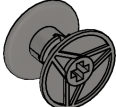

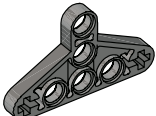

1x
Minifigure, body, white with
flowers
4275536



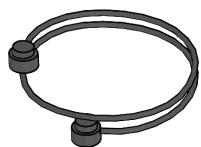
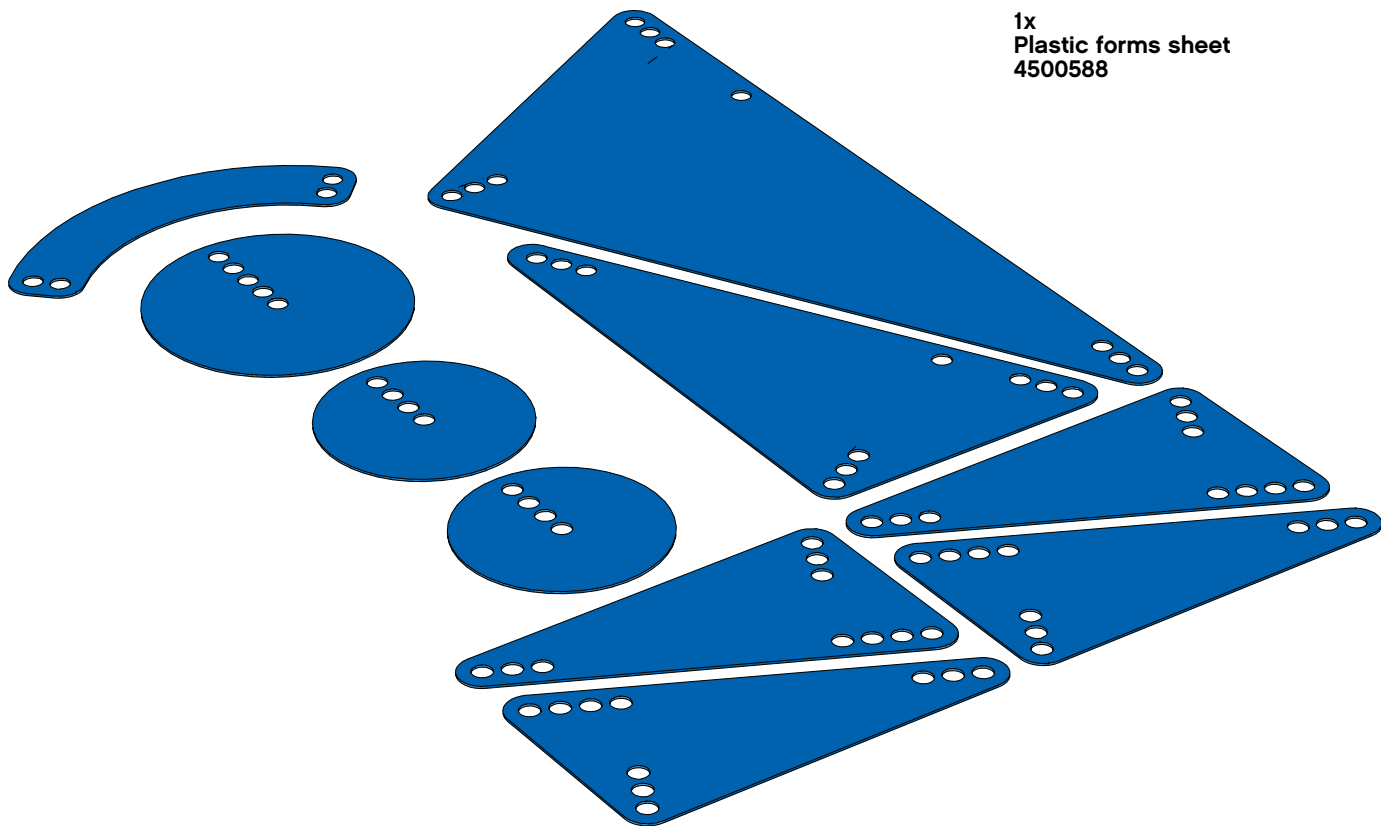
1x
Minifigure, legs, orange
4120158



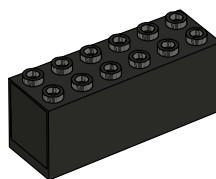
1x
Minifigure, legs, green
74040

	2x Gear, 16-tooth, grey 4211563		2x Belt, 33 mm, yellow 4544151
	4x Gear, 24-tooth crown, grey 4211434		2x Belt, 24 mm, red 4544143
	2x Gear, 40-tooth, grey 4285634		2x Belt, 15 mm, white 4544140
	2x Gear, 10-tooth rack, grey 4211450		1x Universal joint, 3-module, grey 4525904
	2x Worm gear, grey 4211510		4x Hub, 18x14, grey 4490127
	1x Differential, 28-tooth, dark grey 4525184		4x Hub, 24x4, grey 4494222
	4x Gear, 24-tooth, dark grey 4514558		4x Hub, 30x20, grey 4297210
	6x Gear, 8-tooth, dark grey 4514559		6x Connector peg, 1½-module, dark grey 4211050
	2x Gear, 12-tooth double bevel, black 4177431		4x Axle with knob, 3-module, dark grey 4211086
	1x Gear, 14-tooth rack, black 4275503		4x Cam wheel, dark grey 4210759
	6x Gear, 12-tooth bevel, beige 4514556		1x Bobbin, dark grey 4239891
	2x Gear, 20-tooth bevel, beige 4514557		2x ½ beam, triangle, dark grey 4210689
	2x Gear, 20-tooth double bevel, beige 4514555		

1x
Plastic forms sheet
4500588



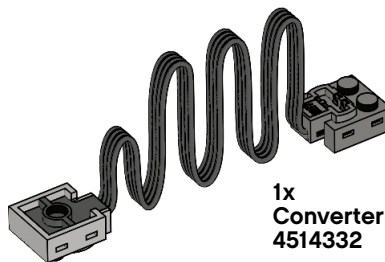
2x
String, 40-module with knobs,
black
4528334



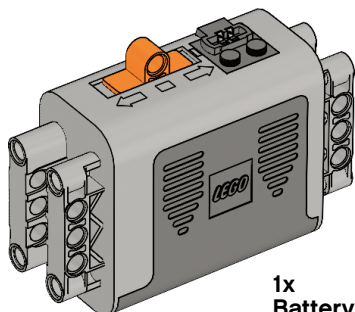
1x
Weight element, black
73843



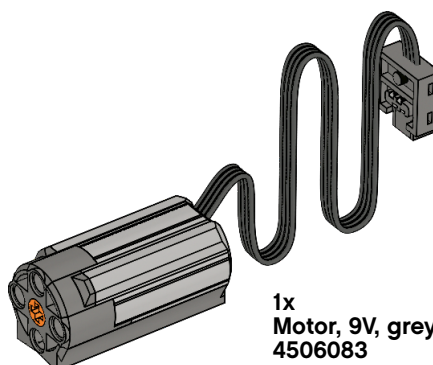
1x
String, 2 m, black
4276325



1x
Converter cable, black
4514332



1x
Battery box, 9V, grey
4506078



1x
Motor, 9V, grey
4506083

