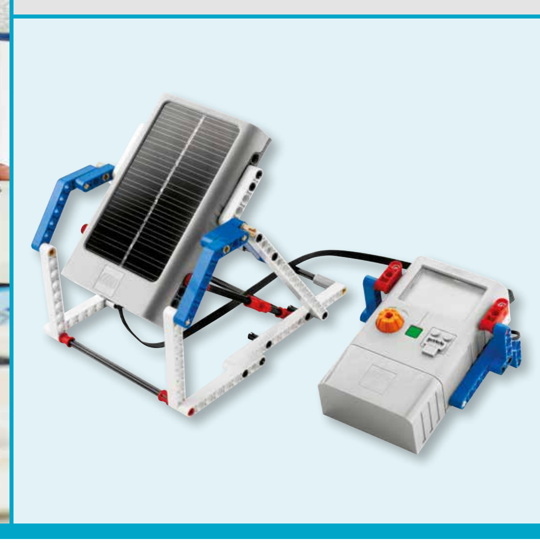
Renewable Energy

Curriculum Pack



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Introduction

LEGO® Education is pleased to bring you the curriculum pack for the Renewable Energy Add-on Set.

Who is it for?

The material is designed for introducing and teaching the topic of renewable energy to middle and high school students. Working in teams, students can build, investigate and learn from the models and activities.

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 'Renewable Energy' curriculum pack and Add-on Set enables students to work as young scientists, engaging them in science, engineering, technology, design and mathematics. The 'Renewable Energy' curriculum pack and Add-on Set promotes a challenging classroom environment and actively engages students in scientific inquiries, reasoning and critical thinking. They are challenged to make assumptions and predictions, bringing together their many experiences and knowledge from different subjects. They utilize their skills, creativity and intuition to actively create new understanding.

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 'Renewable Energy' curriculum pack enables teachers 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

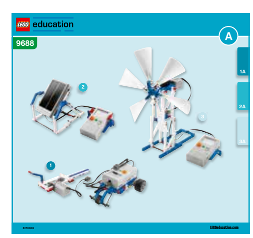
What is in it?

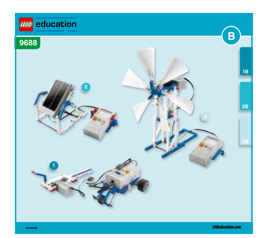
The 9688 Elements

The set consists of five full-color building instructions booklets for the six main model activities, and the following elements: LEGO® Energy Meter (consisting of two separate elements: Energy Display and Energy Storage), LEGO Solar Panel, E-Motor, Blades, LED Lights and a 50 cm (= 19 in.) Extension Wire. This set is an add-on set to be built with the 9686 set. All of the 9688 elements fit into the bottom section of the 9686 storage box.

Building Instructions Booklets

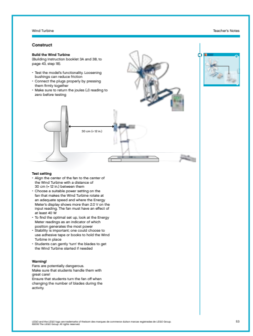
For each of the activity models there are two building instructions, a booklet A and B. The building instructions are designed for two separate building processes, each building only half a model. By combining the two sub-assemblies, students work together to create a single, sophisticated and powerful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

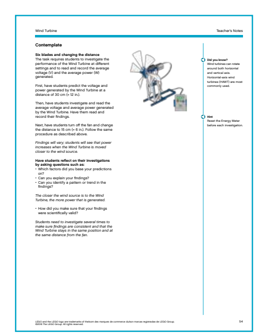




Teacher's Notes

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.

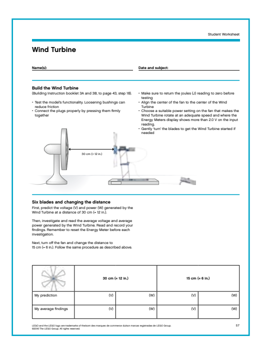


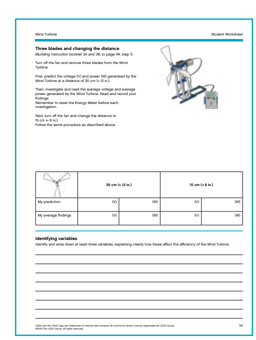


Student Worksheets

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

Students should be encouraged to investigate their predictions at least three times to be confident that their results are reliable. When their main findings are recorded, they discuss their results, reflect on them and adapt ideas. Finally, students are challenged to identify variables and explain clearly how these affected the model's efficiency.





Assessments

Three different assessment materials are provided for all six of the activities and the four 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.

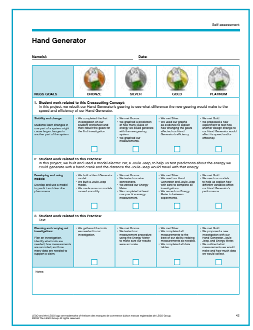
Student Worksheets

The student worksheets should be used to record each student's work throughout each activity. These worksheets are an easy-to-use 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

- **Activity Assessment**

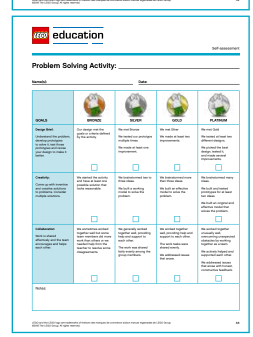
This rubric page can help students to evaluate their activity work according to learning goals based on two science-related NGSS Practices and one theme from the NGSS Crosscutting Concepts.


Hand Generator

- **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?


Problem Solving Activity:

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.

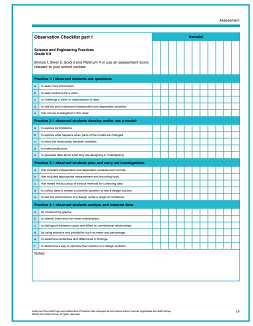
You can also use the rubrics as a tool for your own evaluation of your students' work by marking a grade in the appropriate column and writing optional comments in the 'Notes' section.

- **Observation Checklist**

You can use the observation checklist if a more science and engineering practices assessment approach is required in Problem-Solving Activities. Grades can be recorded on the Observation Checklist provided in the Teacher's Notes in Problem-Solving Activities. Use it to assess individual students, a pair of students or several students.

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 assess students individually, in pairs, or in groups.

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.

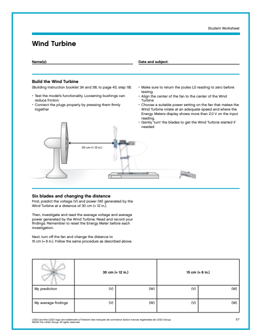


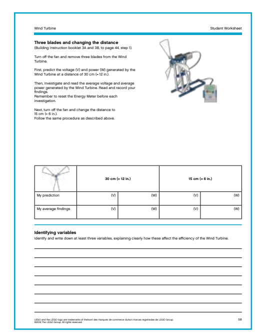
Where can I find the assessment materials?
You can find the assessment materials in the Teacher's Notes for each of the activities and problem-solving activities.

Two Levels of Progression

The 'Renewable Energy' curriculum pack consists of six activities and four problem-solving activities that deal with potential and kinetic energy.

Activities
The six 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 six 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 four 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 worksheet. 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 provides tips on what and how to measure while at the same time carrying out fair testing of the solutions.

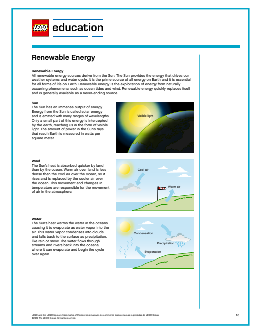
As a support we have included suggested solutions to the problems posed. Use these as 'tips and tricks', or print them and hang them as posters as inspiration for the students. The suggested problem-solving model solutions are only meant as guiding principles for any workable solution the students will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

Teacher's Resources

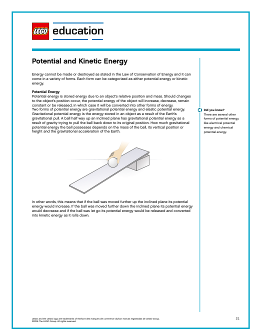
Teacher's Resources contain a short introduction to the topic of renewable energy and a section regarding potential and kinetic energy, an element guide and a glossary with definitions of essential terms.

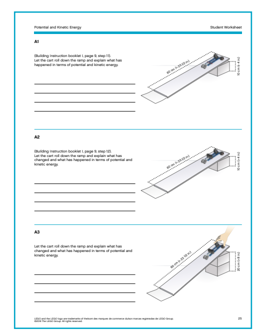
This area contains the following three sections:
• Renewable Energy
• Potential and Kinetic Energy
• Element Guide
Each section includes materials that can be used to present the topic of renewable energy to both students and teachers.

Renewable Energy
This section describes how the sun, as our primary energy source, drives our weather systems and our water cycle. The topic can be presented in class with the help of the illustrations provided. Following the illustrations is an introduction to some of the technologies behind capturing and exploiting renewable energy sources. This section also provides a potential consolidation and clarification of the concept of renewable energy, including a section on class discussion.

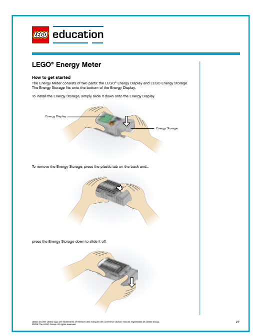


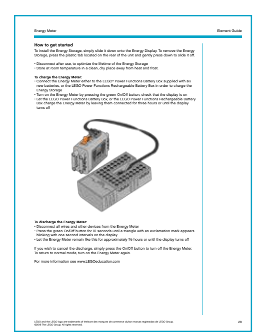
Potential and Kinetic Energy
This section describes how potential and kinetic energy can be introduced to students through hands-on and engaging investigations. Students are challenged to first study the definition and explanations of potential and kinetic energy. While progressing sequentially through the activities using the student worksheets and building instructions booklets, students will be challenged further to apply their knowledge while investigating and recording their findings. In the Teacher's Notes, you will find suggested answers to the questions posed in the student worksheets.





Element Guide
This section describes how to get started with the Renewable Energy Add-on Set (9688). The elements, their features, functionality, technical specifications and their operating instructions are described. Before introducing the main activities, we recommend that you demonstrate the energy meter to your students.





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 according to 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.

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 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.

How much time is needed?
Two class periods are ideal to be able to explore, build and investigate in depth most of the extension ideas built into the activities. For the students to make any creative variations of their own, extra time might be needed with the Hydro Turbine and Wind Turbine activities. However, the remaining activity models can be built, investigated and explored, and the parts put away again within a class period if the students are already experienced LEGO builders.

Students can tackle the problem-solving activities in a sequence of two class periods. However, it is worth organizing this time as two or more back-to-back class periods so that they can immerse themselves in the problem as would a real engineer or designer.

What's needed in my classroom?
Tables may be pushed aside to let models roll across a smooth floor. 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. From teachers and classrooms we have learned that cafeteria-type trays are ideal to build on, and to stop elements rolling onto the floor. 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.

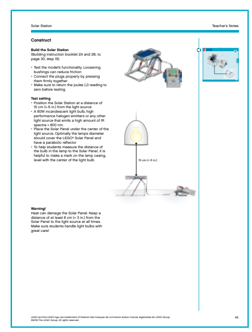
LEGO® Education 4C Approach

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

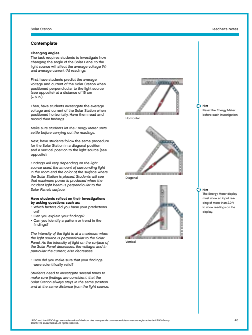
Connect
Connect a new learning experience to those you already have and you add to your knowledge. An initial learning experience is a seed stimulating the growth of new knowledge. Real-life photographs with a short text are provided to help students identify and connect to the chosen activity and the main model.

We suggest using the text and photograph as a starting point for a class discussion or draw on your own experiences to provide an engaging introduction to the activity. Please also consider involving current events related to the topic, both near and far, to set the scene for the students.

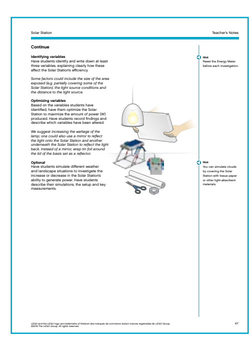
Construct
The construction of models engages both hands and minds. Using the building instructions, students build models embodying the concepts related to the key learning areas. Tips are provided for testing and ensuring each model functions as intended.



Contemplate
Contemplation provides the opportunity to deepen the understanding of previous knowledge and new experiences. The scientific nature of the activities encourages the students to discuss and reflect on their investigations and adapt ideas to the task at hand. This phase provides the opportunity for you to begin evaluating the learning outcome and progress of individual students.



Continue
Continued learning is always more enjoyable and creative when it is adequately challenging. Maintaining a challenge and the pleasure of accomplishment naturally inspires the continuation of more advanced work. Extension ideas are therefore provided to encourage the students to change or add features to their models and to investigate further – always with the key learning area in mind. This phase allows the students to operate at different speeds and levels conducive to their individual capabilities. Activities challenge the students to creatively apply their knowledge and reflect on model design and the effect of changing certain variables.



Curriculum

The process of students actively building, exploring, investigating, inquiring and communicating together develops a vast range of benefits. Here is an overview:

Science
Investigating the collection, storage and transfer of energy; measuring force and speed, and exploring the effect of friction; investigating simple machines, developing scientific fair testing, pursuing purposeful inquiry, predicting and measuring, collecting data and drawing conclusions.

Technology
Designing, making (building), testing and evaluating model solutions to match real needs; choosing appropriate materials and processes; exploring systems and subsystems that transform and transfer energy; using two-dimensional instructions to develop technical understanding; identifying technical components to create three-dimensional working models and working collaboratively in a team.

Engineering
Engineering design, indentifying energy, and investigating and evaluating variables with science, technology, and mathematics are all part of the engineering process.

Mathematics
Using mathematics in the fields of science and technology; measuring distance, time and mass, calculating speed (velocity), and weight and efficiency; using graphical means to present predictions and measurements, tabulating and interpreting data, and informally calculating ratios.

Activity Pack for Renewable Energy Add-on Set Learning Grid

● = Fully covered
◐ = Partially covered

Objective Number	NGSS Grade 6-8	Activities						Problem-Solving Activities			
		Hand Generator	Solar Station	Wind Turbine	Hydro Turbine	Solar Vehicle	Boat Pulley	Lawn Mower	Moving Sign	Motorized Fan	Court Lights
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: Mechanism and explanation	●	●	●	●	●	●	●	●	●	●
3	Scale, proportion, and quantity	●	◐	●	●	●	●	◐	◐	◐	◐
4	Systems and system models	●	●	●	●	●	●	●	●	●	●
5	Energy and matter: Flows, cycles, and conservation	●	●	●	●	●	●	●	●	●	●
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	●	●	●	●	●	●	●	●	●	●

Common Core State Standards Grade 6-8

● = Fully covered
◐ = Partially covered

Objective Number	Common Core State Standards Grade 6-8	Activities						Problem-Solving Activities			
		Hand Generator	Solar Station	Wind Turbine	Hydro Turbine	Solar Vehicle	Boat Pulley	Lawn Mower	Moving Sign	Motorized Fan	Court Lights
Mathematical Practice											
MP1	Make sense of problems and persevere in solving them	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP2	Reason abstractly and quantitatively	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP3	Construct viable arguments and critique the reasoning of others	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP4	Model with mathematics	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP5	Use appropriate tools strategically	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP6	Attend to precision	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP7	Look for and make use of structure	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
MP8	Look for and express regularity in repeated reasoning	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐
Ratios & Proportional Relationships											
6.RP.A	Understand ratio concepts and use ratio reasoning to solve problems	◐			◐	◐	◐				
7.RP.A	Analyze proportional relationships and use them to solve real-world and mathematical problems	◐	◐	◐	◐	◐					
Expressions and Equations											
7.EE.B	Solve real-life and mathematical problems using numerical and algebraic expressions and equations					●	●				
8.EE.B	Understand the connections between proportional relationships, lines, and linear equations	◐	◐	◐	◐	◐	◐				
8.EE.C	Analyze and solve linear equations and pairs of simultaneous linear equations					●	●				
Function											
8.F.B	Use functions to model relationships between quantities	◐			◐	◐	◐				
Speaking and Listening											
SL 6-8.1	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 6-8.4	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	●	●	●	●	●	●	◐	◐	◐	◐
Reading Standards for Literacy in Science and Technical											
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)	●	●	●	●	●	●				
Writing Standards for Literacy in History/Social Studies, Science, & Technical Subjects											
WHST 6-8.1	Obtaining, evaluating, and communicating information	●	●	●	●	●	●	◐	◐	◐	◐
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	●	●	●	●	●	●	◐	◐	◐	◐

Observation Checklist Part 1

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.

		Name(s)										
Practice 1: I observed students asking questions												
a	to seek more information.											
b	to seek evidence for 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

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.

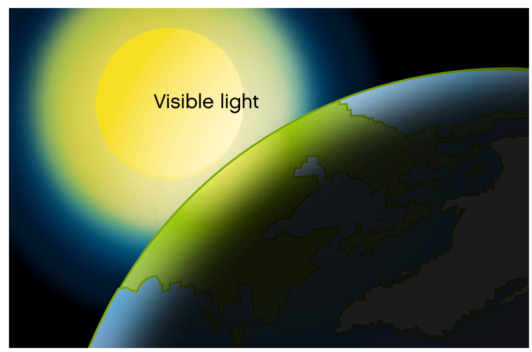
		Name(s)										
Practice 5: I observed students using mathematics and computational thinking												
a	by including mathematical representations in their explanations and design solutions.											
b	by using an algorithm to solve a problem.											
c	by using concepts such as ratio, rate, 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 tradeoffs 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:

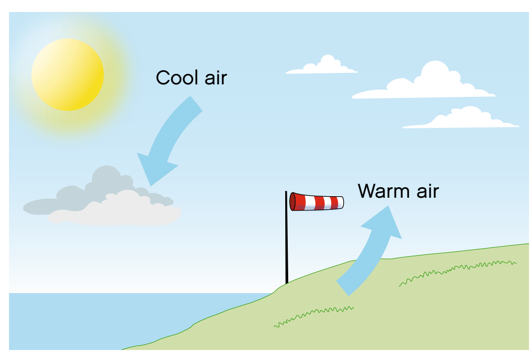
Renewable Energy

Renewable Energy
All renewable energy sources derive from the Sun. The Sun provides the energy that drives our weather systems and water cycle. It is the prime source of all energy on Earth and it is essential for all forms of life on Earth. Renewable energy is the exploitation of energy from naturally occurring phenomena, such as ocean tides and wind. Renewable energy quickly replaces itself and is generally available as a never-ending source.

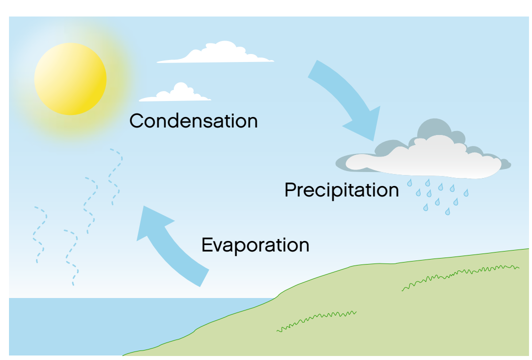
Sun
The Sun has an immense output of energy. Energy from the Sun is called solar energy and is emitted with many ranges of wavelengths. Only a small part of this energy is intercepted by the earth, reaching us in the form of visible light. The amount of power in the Sun's rays that reach Earth is measured in watts per square meter.



Wind
The Sun's heat is absorbed quicker by land than by the ocean. Warm air over land is less dense then the cool air over the ocean, so it rises and is replaced by the cooler air over the ocean. This movement and changes in temperature are responsible for the movement of air in the atmosphere.



Water
The Sun's heat warms the water in the oceans causing it to evaporate as water vapor into the air. This water vapor condenses into clouds and falls back to the surface as precipitation, like rain or snow. The water flows through streams and rivers back into the oceans, where it can evaporate and begin the cycle over again.



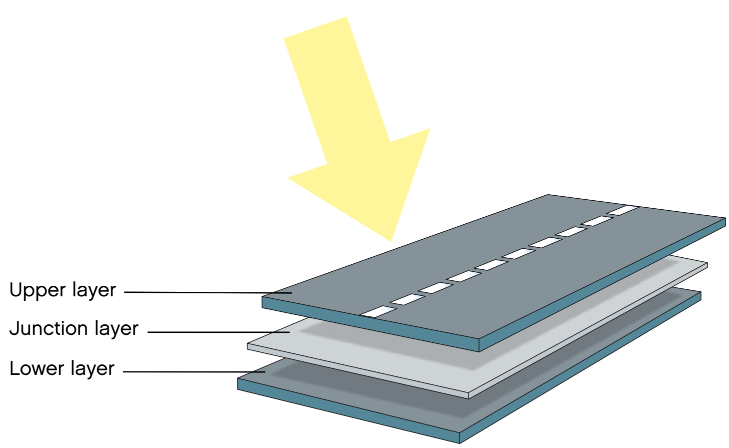
Solar Energy

Solar energy can be captured, for example, by solar cells. Many solar cells assembled together are called solar panels. Solar panels are designed to capture the suns energy and convert it to more exploitable forms, such as heat or electricity. Technologies linked to solar energy are:

- **Passive solar energy**, in which the energy in sunlight is used for light and heat. In passive solar building design the Sun's energy contribution is fully optimized.

- **Active solar water heating systems**, in which the Sun's heat energy is transferred to special fluids held in solar collectors. This fluid is pumped through pipes in water tanks and the heat energy transferred to the water.

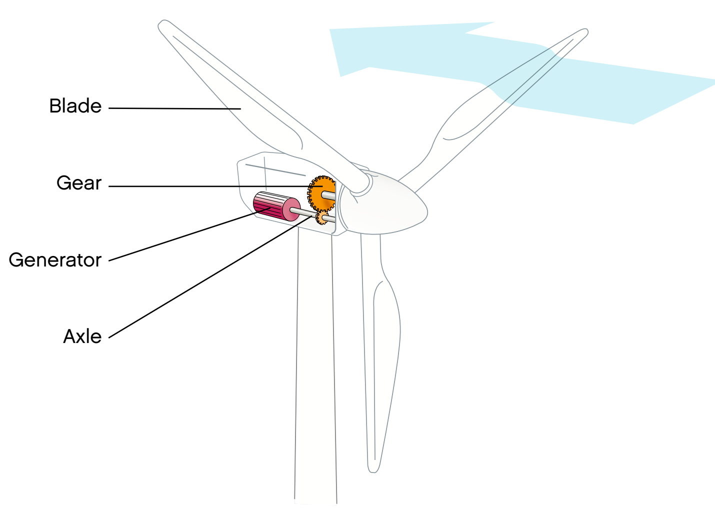
- **Photovoltaics**, in which the energy in visible light from the Sun is converted directly into an electric current by means of solar cells. Using the photoelectric effect, loose electrons in the upper layer of the solar cell are caused to move, thus creating an electric current that can be used to operate an electrical device.



Wind Energy

Wind energy can be captured by wind turbines. Wind turbines are designed to capture the wind's energy and convert it into a more useful form, such as electricity.
Technologies linked to wind energy are:

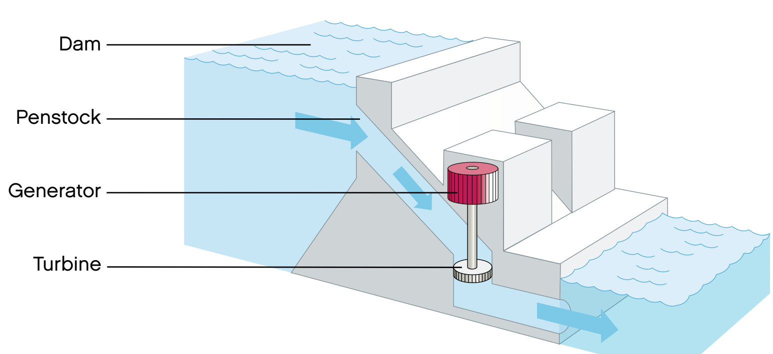
- **Wind turbines with a vertical axis** have a rotating axis and blades in a vertical position. They work equally effectively, irrespective of wind direction.
- **Wind turbines with a horizontal axis** have a rotating axis and blades in a horizontal position. They must be faced with respect to wind direction and are the most common type of wind turbine to be found, both onshore and offshore.
- **Wind turbines, whether onshore or offshore**, can generate the same amount of power. The key issue of efficiency lies in where the turbines are placed. Offshore wind turbines are often considered more reliable due to the wide open spaces at sea where wind is able to gain energy. Onshore and offshore wind turbines have the same basic parts: tall towers, large turbine blades, axles, gears and a generator.



Hydro Energy

Hydro energy can be captured, for example, by hydro turbines. Hydro turbines are designed to capture the energy in moving water and convert it into a more useful form, such as electricity. Technologies linked to hydro energy are:

- **Wave energy**, in which the energy in the wave motion of the ocean is captured and used to generate electricity. The waves can be funneled into a channel or basin to increase their size and hence the available energy. This energy is then used to spin turbines, which in turn drive a generator that generates electricity.
- **Tidal energy**, in which the energy in the tidal current is captured and used to generate electricity. A tidal barrage is built across an estuary or inlet. The barrage has gates in it that allow the water to pass through. When the tide has stopped flowing through the gates, they are closed, creating a large head of water. When the tide flows back, the receding water is channeled through turbines in the gates that generate electricity.
- **Hydroelectric power plants**, in which the energy from water in movement is extracted to generate electricity. Most large-scale hydro power plants control the water in reservoirs or dams and channel the water through pipes, also called penstocks, causing the water to flow faster and driving turbines to generate electricity.



For Further Discussion in Class

The following discussion points are optional, but might help provide a potential consolidation and clarification of the renewable energy concept. They provide the opportunity for students to share their impressions on what energy is and to gain an understanding of different developments dealing with renewable energy. Depending on the student's personal experience or observations, answers will vary. It is important that different viewpoints and explanations are valued and used to build up an overall understanding that is moving towards scientific understanding.

- **What is energy?**
  Energy is the capacity or ability to do work. Energy is a vital part of our everyday lives. Energy can be stored to be used later and energy can change from one form to another. Energy cannot be made or destroyed as stated in the Law of Conservation of Energy.

- **How is the Sun's energy transferred to Earth and how do we depend on this?**
  The Sun is our primary source of energy. When it is transferring radiation energy to the earth, e.g., as light waves, it causes such phenomena as plant growth, wind, ocean currents, and the water cycle.

- **How do you define a renewable and a non-renewable energy source?**
  Energy derived from naturally occurring and inexhaustible sources, like solar, wind and hydro, are all renewable energy sources. Energy derived from a finite source, like coal, oil and gas, are non-renewable energy sources.

- **How many domestic electrical appliances have you been in contact with since you woke up?**
  Electricity is the main source of energy in our homes. Electrical energy can be changed to make light energy, heat energy, and sound energy. Students may have been in contact with an electrical alarm or a mobile phone, some may have turned on a light, a radio or the television, some might also have used an electric kettle or opened a refrigerator.

- **Do you know any energy-efficient appliances or other ways we can save on energy?**
  Newer electrical appliances will usually have an energy rating; students can check these. Or alternatively, check some of the school's electrical appliances. Replacing incandescent light bulbs with energy saving light bulbs also saves energy. Other ways of saving energy could be by turning off the lights if the Sun is shining in, by turning off the computer or television instead of switching to standby mode and by simply minimizing electrical needs.

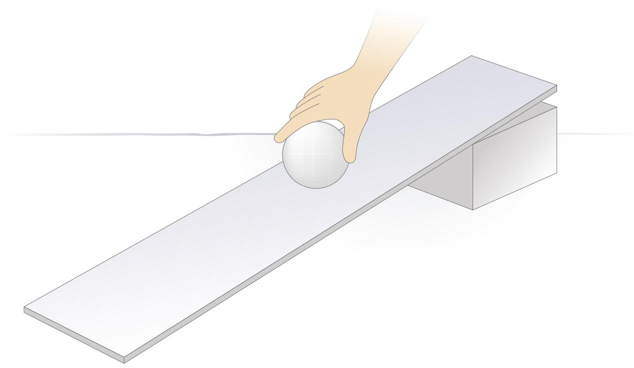
- **Do you know of any examples of how a renewable energy source is being used in your area?**
  It is likely that student's knowledge will vary and might also be conflicting. Here is an interesting opportunity for the class to find out the facts and learn more about the way information can be presented. Information varies according to vested interests. From an activity such as this, the class might draw up a list of the advantages and disadvantages of different renewable energy sources. When listing, they can consider specific social, economic, political and/or environmental interests.

Potential and Kinetic Energy

Energy cannot be made or destroyed as stated in the Law of Conservation of Energy and it can come in a variety of forms. Each form can be categorized as either potential energy or kinetic energy.

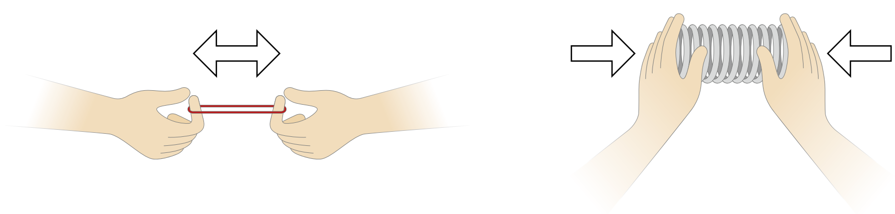
Potential Energy
Potential energy is stored energy due to an object's relative position and mass. Should changes to the object's position occur, the potential energy of the object will increase, decrease, remain constant or be released, in which case it will be converted into other forms of energy.
Two forms of potential energy are gravitational potential energy and elastic potential energy. Gravitational potential energy is the energy stored in an object as a result of the earth's gravitational pull. A ball half way up an inclined plane has gravitational potential energy as a result of gravity trying to pull the ball back down to its original position. How much gravitational potential energy the ball possesses depends on the mass of the ball, its vertical position or height and the gravitational acceleration of the earth.

Did you know?
There are several other forms of potential energy, like electrical potential energy and chemical potential energy.



In other words, this means that if the ball was moved further up the inclined plane its potential energy would increase. If the ball was moved further down the inclined plane its potential energy would decrease and if the ball was let go its potential energy would be released and converted into kinetic energy as it rolls down.

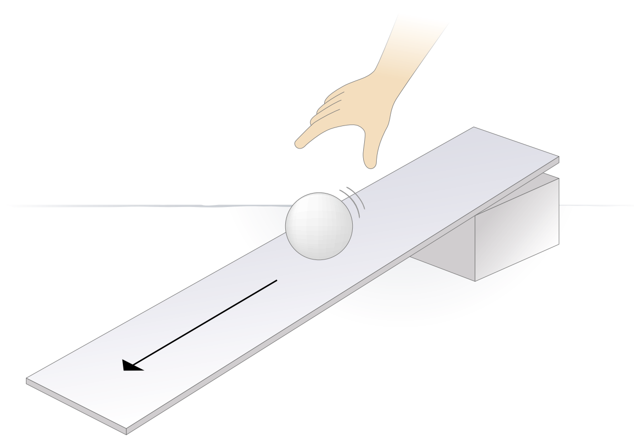
Elastic potential energy is the stored energy of an object that is being stretched, squashed or twisted. Sometimes solid materials are shaped especially so that they are good at storing elastic potential energy. This is true for springs and elastic bands. A stretched elastic band has stored elastic potential energy as a result of the elastic band trying to assume its natural shape. Exactly how much stored elastic potential energy there is, will depend on the characteristics of the band and the amount of force it is subjected to. The same applies for a spring.



In other words, this means the more you stretch it the more elastic potential energy it will contain. If you let go of the elastic band its potential energy will be released and converted to kinetic energy as the elastic band contracts and returns to its original shape.

Kinetic Energy
Kinetic energy is the energy a body has by virtue of its motion. Whenever an object is in motion, whether it is vertical, horizontal, and rotational or simply moving from one location to another, it has kinetic energy.

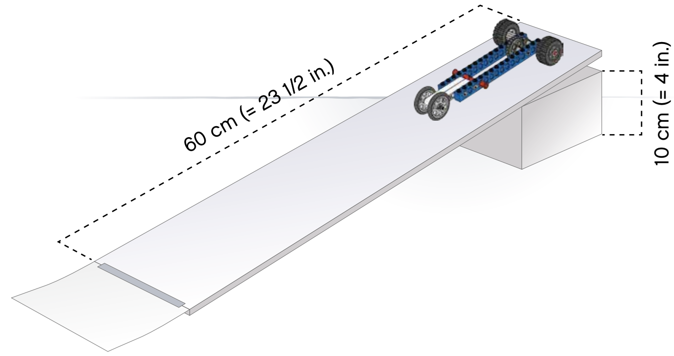
The ball that is being held half way up the inclined plane has potential energy but no kinetic energy, as it is not moving. If the ball is released and it started to roll down the inclined plane it would be gaining kinetic energy. How much it gains will depend on its mass and velocity.



In other words, this means that a heavier ball rolling down the inclined plane will have more kinetic energy than a lighter ball rolling from the same position. A ball rolling from the top of the inclined plane will be traveling faster by the time it reaches the bottom of the inclined plane than a ball of the same mass released from half way up the inclined plane. It will have more kinetic energy than the slower moving ball of the same mass simply because it is moving faster.

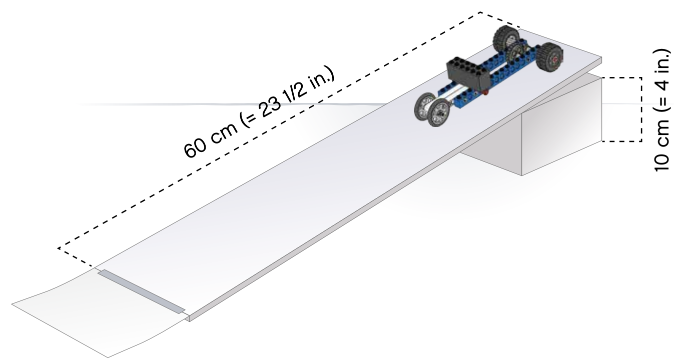
A1

Potential energy is transformed to kinetic energy as the cart rolls down the ramp. The cart has greatest potential energy at its starting point and greatest kinetic energy at the bottom of the ramp.



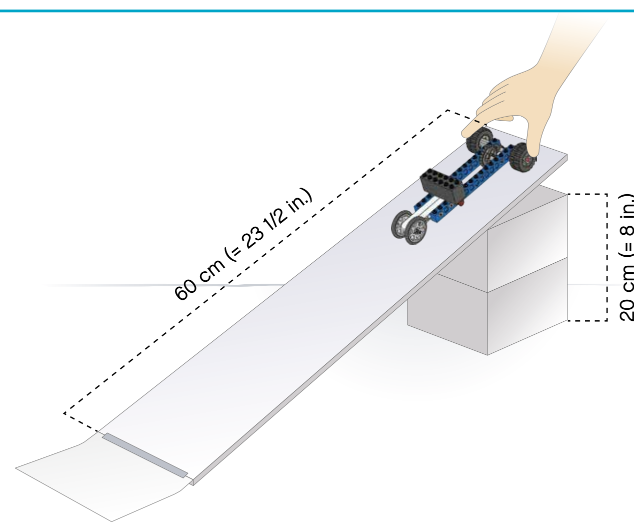
A2

Addition of mass to the cart constitutes an increase in potential energy. As the cart rolls down the ramp, potential energy is transformed to kinetic energy. The increase of potential energy and kinetic energy makes the cart travel further and faster.



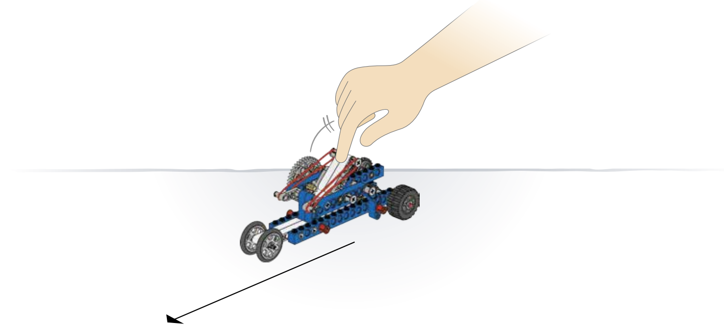
A3

Addition of height to the ramp constitutes a further increase in the potential energy of the cart still with the additional mass. As the cart rolls down the ramp, potential energy is transformed to kinetic energy. The increase of potential energy and kinetic energy makes the cart travel even further and even faster.



A4

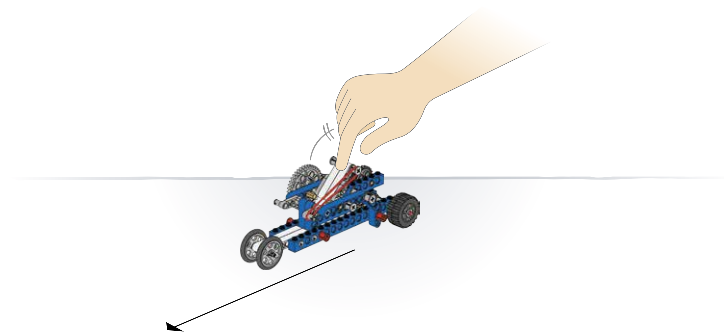
As the handle of the cart is pulled back the elastic band increases its potential energy. As the handle is let go, potential energy is transformed to kinetic energy and the cart moves.



A5

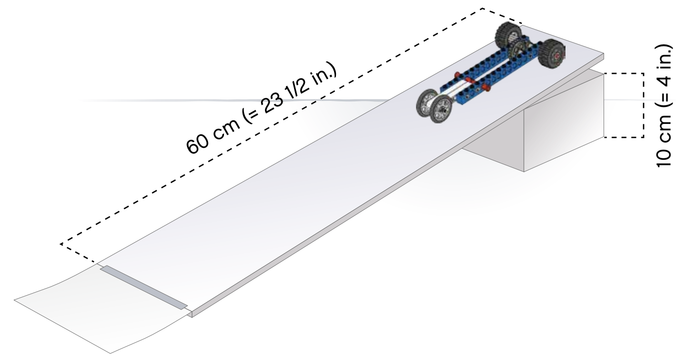
Due to the removal of an elastic band, there is a decrease in potential energy, which makes the cart move a shorter distance.

As the handle of the cart is pulled back the elastic band increases its potential energy. As the handle is let go, potential energy is transformed to kinetic energy and the cart moves.



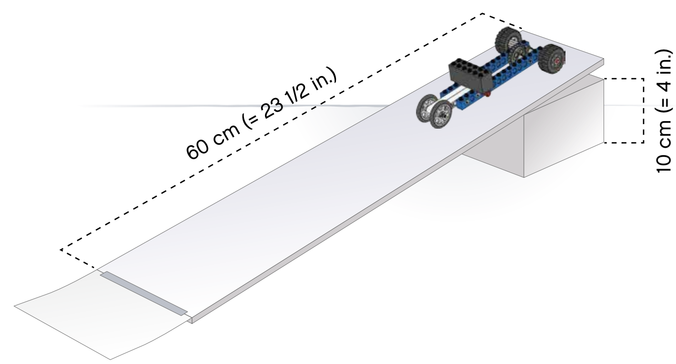
A1

(Building instruction booklet I, page 9, step 11)
Let the cart roll down the ramp and explain what has happened in terms of potential and kinetic energy.



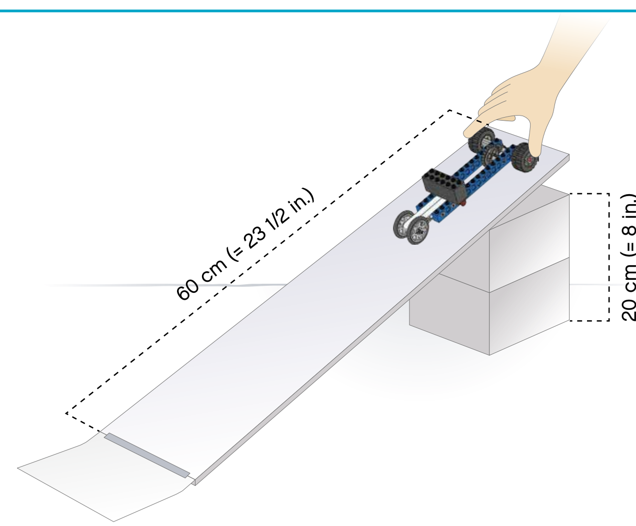
A2

(Building instruction booklet I, page 9, step 12)
Let the cart roll down the ramp and explain what has changed and what has happened in terms of potential and kinetic energy.



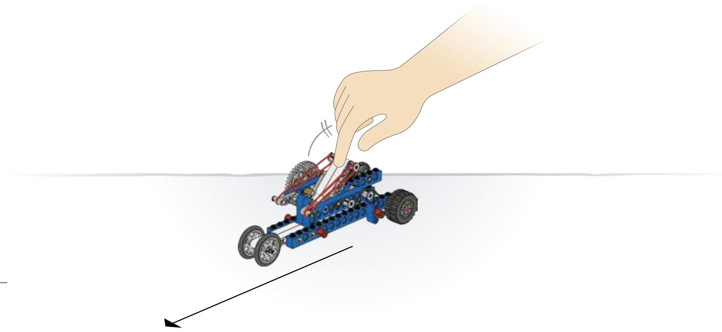
A3

Let the cart roll down the ramp and explain what has changed and what has happened in terms of potential and kinetic energy.



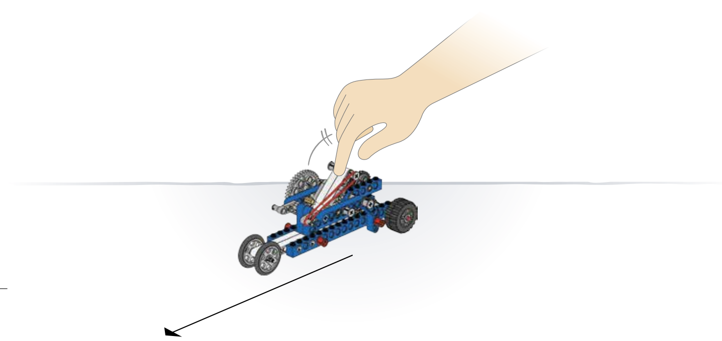
A4

(Building instruction booklet I, page 18, step 27)
Pull the handle back as far as it goes, then let go and watch the car move. Explain what has happened in terms of potential and kinetic energy.



A5

(Building instruction booklet I, page 19, step 28)
Pull the handle back as far as it goes, then let go and watch the car move. Explain what has changed and what has happened in terms of potential and kinetic energy.

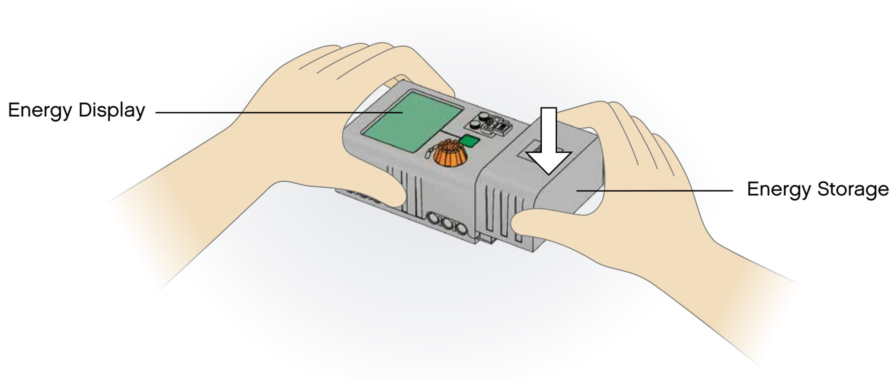


LEGO® Energy Meter

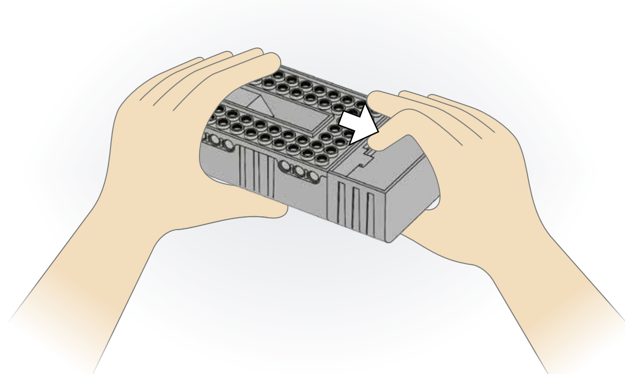
How to Get Started

The Energy Meter consists of two parts: the LEGO® Energy Display and LEGO Energy Storage. The Energy Storage fits onto the bottom of the Energy Display.

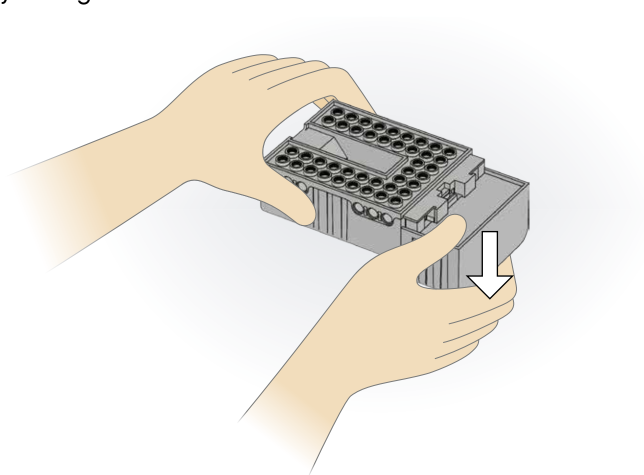
To install the Energy Storage, simply slide it down onto the Energy Display.



To remove the Energy Storage, press the plastic tab on the back and...



press the Energy Storage down to slide it off.



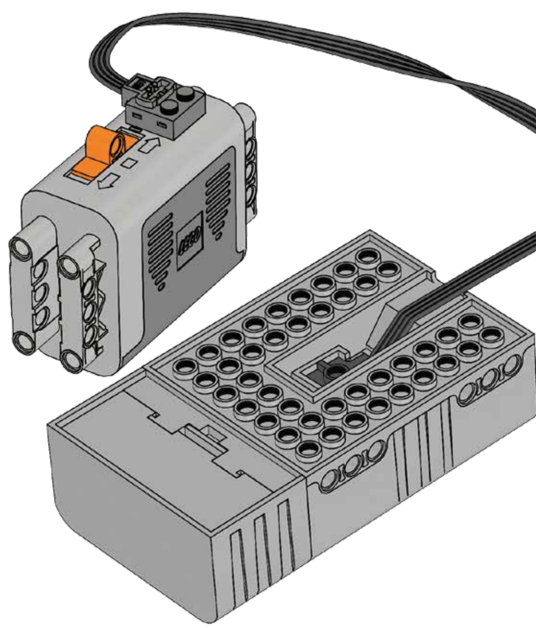
How to Get Started

To install the Energy Storage, simply slide it down onto the Energy Display. To remove the Energy Storage, press the plastic tab located on the rear of the unit and gently press down to slide it off.

- Disconnect after use, to optimize the lifetime of the Energy Storage
- Store at room temperature in a clean, dry place away from heat and frost.

To charge the Energy Meter:

- Connect the Energy Meter either to the LEGO® Power Functions Battery Box supplied with six new batteries, or the LEGO Power Functions Rechargeable Battery Box in order to charge the Energy Storage
- Turn on the Energy Meter by pressing the green On/Off button, check that the display is on
- Let the LEGO Power Functions Battery Box, or the LEGO Power Functions Rechargeable Battery Box charge the Energy Meter by leaving them connected for three hours or until the display turns off



To discharge the Energy Meter:

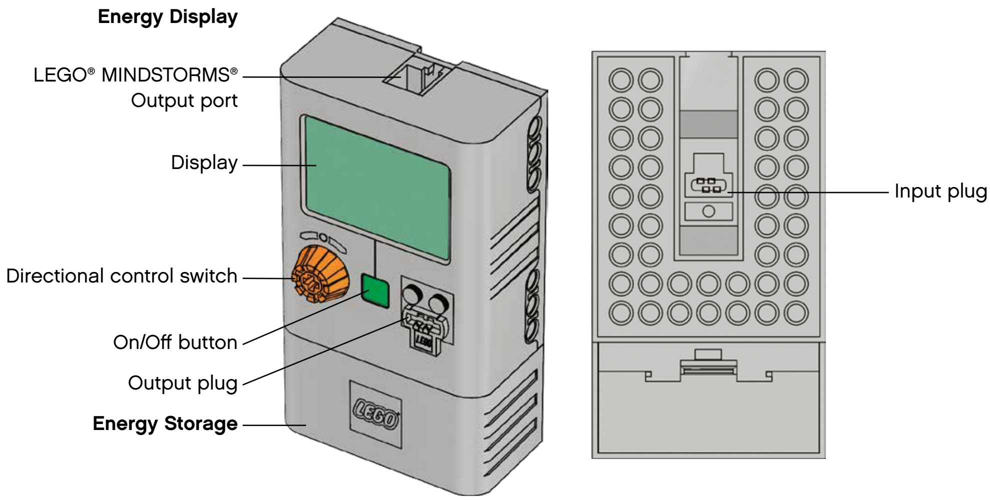
- Disconnect all wires and other devices from the Energy Meter
- Press the green On/Off button for 10 seconds until a triangle with an exclamation mark appears blinking with one second intervals on the display
- Let the Energy Meter remain like this for approximately 1½ hours or until the display turns off

If you wish to cancel the discharge, simply press the On/Off button to turn off the Energy Meter. To return to normal mode, turn on the Energy Meter again.

For more information see www.LEGOeducation.com

How It Works
The Energy Meter can measure, store and release generated energy.

Functionality



Energy Display

MINDSTORMS Output Port
For more on how to use the Energy Meter together with LEGO MINDSTORMS, see www.MINDSTORMSeducation.com

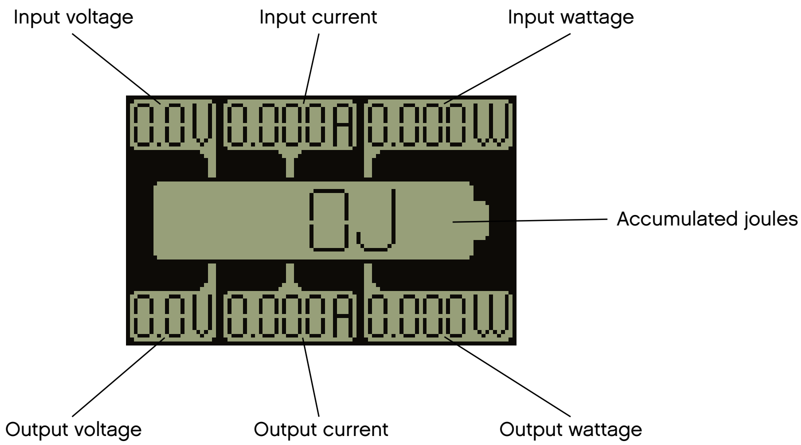
Directional Control Switch
Use the directional control switch to operate the output function. By turning the switch in either direction with power on you can control the output function. In the middle position, the output function is off.

On/Off Button
Press the On/Off button down once to turn the Energy Meter on and once more to turn it off. Pressing down and holding the On/Off button down for two seconds will reset joules measurement to 0 J.

Output Plug
Connect the E-Motor to the output plug and read the Energy Meter's power output. A minimum of 1 J must be stored before an output can be drawn from the Energy Meter.

Input Plug
Connect the Solar Panel or E-Motor, used as a generator to the input plug and read the Energy Meter measurements.

Display Measurements



Accumulated Joules

The maximum amount of accumulated joules that can be stored is 100 J. The reading of 100 J will start blinking on the display with one second intervals when this maximum is reached. Input voltage will remain measured in the display, but input current and input wattage will go to zero. The output measurements will depend on the load applied. Pressing down and holding the On/Off button for two seconds will reset the joules measurement to 0 J. Please note that this is not an indication of the charged status of the Energy Storage.

Blinking Lightning Symbol

A lightning symbol appears blinking with one second intervals on the display, when one of two possible situations have occurred:

- If the number of joules remains the same, then you should be able to continue your activity, but the Energy Storage power level is low and you should soon charge the Energy Meter.
  The Energy Storage should be charged before each lesson.
- If the number of joules resets to 0 J and output voltage goes to zero, then the Energy Meter has been overloaded and must be recharged.
  Do not overload the Energy Meter.

Constant Lightning Symbol

A constant lightning symbol appears on the Energy Meter display when the Energy Storage needs to be charged.

Error

A triangle with an exclamation mark appears on the display when there is an error on the Energy Storage. Measurements are not valid. Remove the Energy Storage, check the connecting parts and see if they need cleaning. Reconnect the Energy Storage to the Energy Display and charge the Energy Meter. If the error triangle reappears, replace with a new Energy Storage.

Energy Storage
The Energy Storage stores the energy you have generated. Measurements on the Energy Display are not valid when disconnected from the Energy Storage. The lifespan of the Energy Storage depends heavily on the way it is used, maintained and stored. Store the Energy Storage at room temperature in a clean, dry place away from heat. Heat, frost and long discharge periods can significantly shorten the expected lifespan of the Energy Storage. Disconnect the Energy Storage after use. It is necessary to recharge the Energy Storage after a long storage period.

Technical Specifications
The Energy Meter will display measurements in the range of:
- 0.0 V to 9.9 V, input voltage
- 0.000 A to 0.200 A, input current
- P = V x I, P = input wattage
- 0 J to 100 J, accumulated joules
- 0.0 V to 9.9 V, output voltage
- 0.000 A to 0.450 A, output current
- P = V x I, P = output wattage

Refresh Rate and Averaging Measurements
Display measurements are refreshed every 0.5 seconds; they are calculated by averaging the measurements at equal intervals of 100 per 0.5 seconds. Depending on the input, this should give fairly constant and easily identifiable measurements.

Take Good Care of Your Energy Meter
- Do not bend or push hard on it or elements connected to it
- Do not step on or otherwise place heavy weights on it
- Do not drop it
- Do not short circuit it
- Do not exceed the maximum 10 V supply voltage
- Do not overload the Energy Meter as this will cause it to discharge
- It is not waterproof
- Store at room temperature in a clean, dry place away from heat and frost
- The Energy Storage should be charged before each lesson

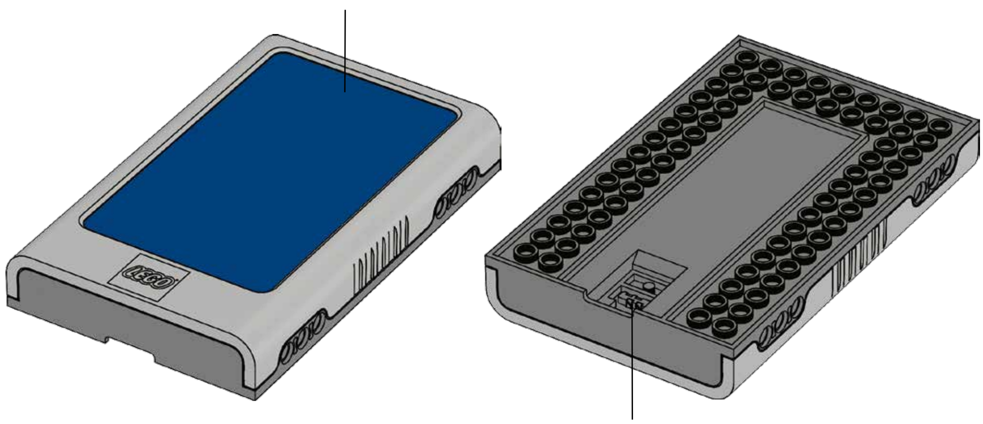
LEGO® Solar Panel

How It Works

Solar Panels can convert solar energy into electrical energy. The ideal light source is full natural sunlight. When incandescent light bulbs are used, be cautious, they produce a lot of heat and the light bulb should only be on for short periods at a time. Also keep the light bulb at a reasonable distance from the Solar Panel (at least 8 cm or 3 in.) and increase the distance or turn off the light bulb if the Solar Panel gets hot.

Do not use energy saving light bulbs; the light they emit is insufficiently bright. An energy saving light bulb emits a very low amount of light in the IR range 800 + nm.

Functionality



Solar Panel

The Solar Panel consists of fourteen solar cells and four diodes, with a total voltage output of approximately 7 V.

Output Plug

The output plug lets you transfer the energy from the Solar Panel to elements like the LEGO® Energy Meter or the E-Motor.

Technical Specifications

With optimal light settings the Solar Panel provides sufficient power to operate the Energy Meter and E-Motor. It delivers:

- 6.5 V, 100 mA > at 100,000 lux, daylight outdoors
- 6.5 V, 50 mA > at 50,000 lux, indoor sunlight
- 5 V, 4 mA > at 2,000 lux, 60 W incandescent bulb positioned 25 cm (= 10 in.) from the Solar Panel
- 5 V, 20 mA > at 10,000 lux, 60 W incandescent bulb positioned 8 cm (= 3 in.) from the Solar Panel

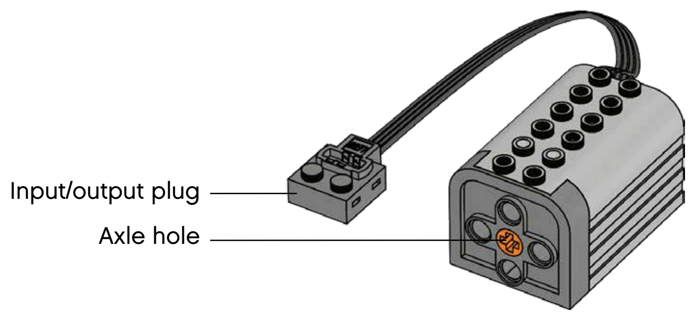
Take Good Care of Your Solar Panel

- Do not bend or push hard on it or elements connected to it
- Do not step on or otherwise place heavy weights on it
- Do not drop it
- Do not short circuit it
- Keep the light bulb at a reasonable distance from the Solar Panel at least 8 cm (= 3 in.) and increase the distance or turn off the light bulb if the Solar Panel gets hot
- It is not waterproof
- Store at room temperature in a clean, dry place away from heat and frost

E-Motor

How It Works
The E-Motor is a 9 V motor with an internal gearbox. The E-Motor can also work as a generator of electrical energy.

Functionality



Axle Hole
Insert an axle and make it turn to use the E-Motor as either a motor or a generator.

Input/Output Plug
The input/output plug allows you to transfer electrical energy from the E-Motor to elements like the Energy Meter and LED Lights, or to transfer electrical energy to the E-Motor from elements like the Solar Panel or the Energy Meter.

Technical Specifications
Without load its rotation speed is around 800 rotations per minute and it delivers:
- Maximum torque of 4.5 N/cm
- 9 V motor
- 9.5:1 gearing
- 20 cm (= 8 in.) wire

Take Good Care of Your E-Motor
- Do not bend or push hard on it or elements connected to it
- Do not step on or otherwise place heavy weights on it
- Do not drop it
- Do not short circuit it
- Do not exceed the maximum 9 V supply voltage
- Do not leave it in a stalled condition
- It is not waterproof
- Store at room temperature in a clean, dry place away from heat and frost

Hand Generator

Science
- Transfer of energy
- Storage of energy
- Conversion of energy
- Scientific investigation
- Systematic observation
- Interpretation of evidence

Technology
- Constructing models
- Product design
- Evaluating
- Using mechanisms-gears

Engineering
- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics
- Applications of angles, ratios, and proportion
- Informal and formal measuring of distance/time/speed/work
- Graphing
- Selecting appropriate methods for estimating and measuring

Vocabulary
- Efficiency
- Distance
- Joules
- Work

Other Materials Required
- Graph paper
- Ruler or measuring tape
- Stopwatch or timer

Connect

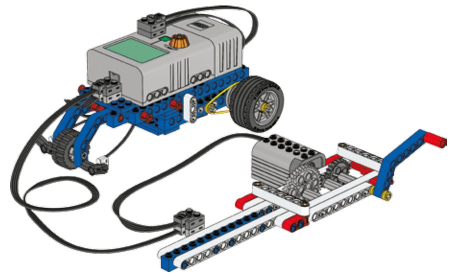
Generators have the ability to convert mechanical energy into electrical energy. The human body can operate a generator by turning the handle. The faster we turn the handle the more electricity we generate.

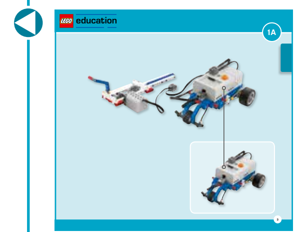
Now build the hand generator and investigate its ability to generate power.

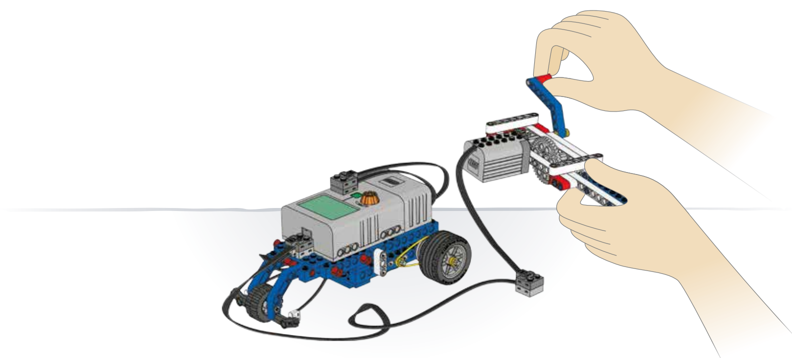
Construct

Build the Hand Generator and the Joule Jeep
(building instructions booklets 1A and 1B, to page 15, step 16)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing

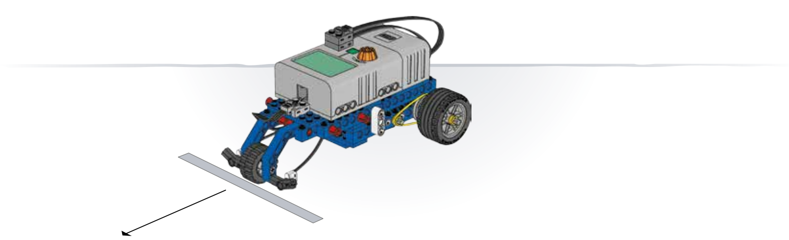






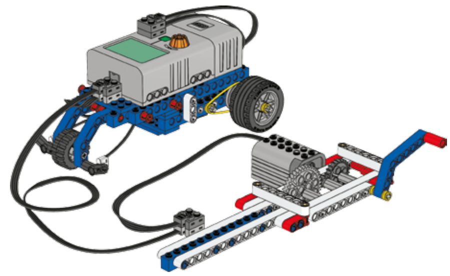
Test Setting

- Mark a start line for your joule jeep



Contemplate

Turn and Go
The task requires students to investigate how many joules (J) the hand generator can accumulate after a time period of 60 seconds and see how far these joules can power the joule jeep.



First, have students graph their prediction in a system of coordinates showing how many joules they will accumulate after a time period of 60 seconds.

Then, have students investigate how many joules they can accumulate by turning the handle of the hand generator during a period of 60 seconds. Have them read and record their findings at 10 second intervals and have them graph their findings in the same system of coordinates as their prediction.

Next, have students find out how far the joule jeep can run on the amount of accumulated joules.

Findings will vary; students will see that the distance traveled by the joule jeep will vary depending on the amount of accumulated joules.

Have students reflect on their investigations by asking questions, such as:
- Which factors did you base your predictions on?
- Can you explain your findings?
- Can you identify a pattern or trend in the findings?

For a given time, the amount of accumulated joules is proportional to the speed of turning the handle.

- How did you make sure that your findings were scientifically valid?

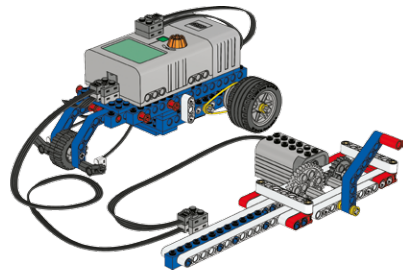
Students need to investigate several times to make sure findings are consistent and that the joule jeep starts and runs from the same spot and on the same track surface.

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

Hint
Reset the Energy Meter before each investigation.

Continue

Gearing Up
(building instructions booklets 1A and 1B, to page 16 step 1).



The task requires students to investigate how many joules (J) the rebuilt hand generator can accumulate after a time period of 60 seconds and then see how far these joules can power the joule jeep.

First, have students rebuild the hand generator's gearing. Then, based on their knowledge of specific characteristics of gears, have them graph their prediction in a system of coordinates showing how many joules they will be able to accumulate over a time period of 60 seconds.

Then, have students investigate how many joules they can accumulate by turning the handle of the hand generator during a period of 60 seconds. Have them read and record their findings at 10 second intervals and have them graph their findings in the same system of coordinates as their prediction.

Next, have students find out how far the joule jeep can run on the amount of accumulated joules.

Findings will vary, but a significant increase in the amount of joules accumulated will be seen. Ideally, students should predict a 60% increase in the amount of joules accumulated. How far the joule jeep will travel will vary depending on the amount of accumulated joules.

Identifying variables
Have students identify and write down at least three variables, explaining clearly how these affect the efficiency of the hand generator and the joule jeep.

Some factors could include the effects of changing the gearing, the length of the handle, the speed with which the handle is turned, the strength and stamina of the person turning the handle and the structural stability of the hand generator. The joule jeep's efficiency is influenced by its weight, gearing, friction and the track surface.

Did you know?
The unit for the energy producing potential in food is calories (cal). One calorie is generally assumed to be 4.2 J.

Hint
Reset the Energy Meter before each investigation.

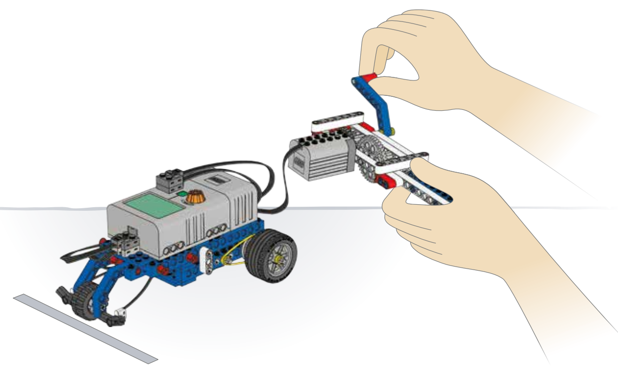
Hand Generator

Name(s): ______________________ **Date and subject:** ______________________

Build the Hand Generator and the Joule Jeep

(building instructions booklets 1A and 1B, to page 15, step 16).

- Test the models functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing
- Mark a start line for your joule jeep



Turn and Go

First, predict how many generated joules (J) you will be able to accumulate by turning the handle of the hand generator after a time period of 60 seconds (sec.).

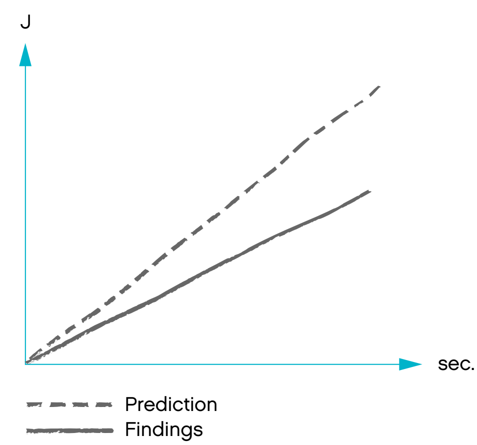
Graph your prediction in a system of coordinates as illustrated opposite.

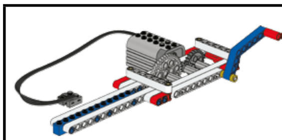
Then, investigate the amount of joules accumulated at 10 second intervals. Read and record your findings.

Graph your findings in the same system of coordinates as your prediction. Remember to reset the Energy Meter before each investigation.

Next, mark a starting line for your joule jeep and find out how far the Joule Jeep can run on the amount of accumulated joules.

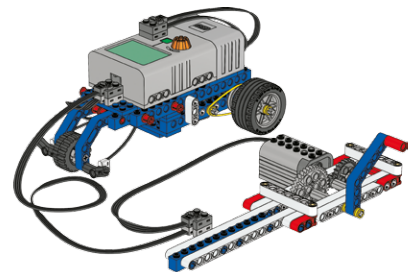
My joule jeep traveled a distance of: ______________________



	10 sec.	20 sec.	30 sec.	40 sec.	50 sec.	60 sec.
My Prediction	(J)	(J)	(J)	(J)	(J)	(J)
My Findings	(J)	(J)	(J)	(J)	(J)	(J)

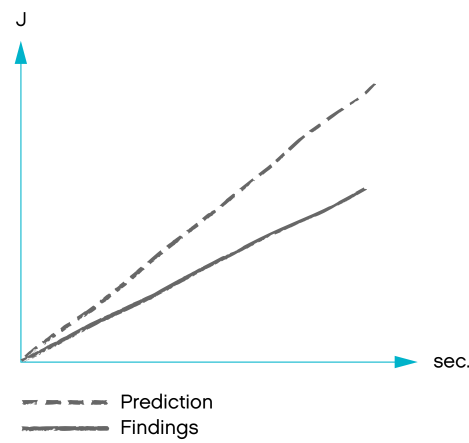
Gearing Up

(building instructions booklets 1A and 1B, to page 16, step 1)



First, rebuild the hand generator's gearing. Look carefully to see what difference the new gearing will make to the speed. Predict how many generated joules (J) you will be able to accumulate by turning the handle of the hand generator after a time period of 60 seconds (sec.).

Graph your prediction in a system of coordinates as illustrated opposite.

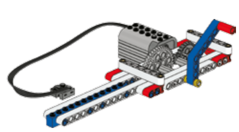


Then, investigate the amount of joules accumulated at 10 second intervals. Read and record your findings.

Graph your findings in the same system of coordinates as your prediction. Remember to reset the Energy Meter before each investigation.

Next, mark a starting line for your joule jeep and find out how far the joule jeep can run on the amount of accumulated joules.

My joule jeep traveled a distance of: ______________________

	10 sec.	20 sec.	30 sec.	40 sec.	50 sec.	60 sec.
My Prediction	(J)	(J)	(J)	(J)	(J)	(J)
My Findings	(J)	(J)	(J)	(J)	(J)	(J)

Identifying Variables

Identify and write down at least three variables, explaining clearly how these affect the efficiency of the hand generator and joule jeep.

Hand Generator

Name(s): ______________________ **Date:** ______________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we rebuilt our hand generator's gearing to see what difference the new gearing would make to the speed and efficiency of our hand generator.				
Stability and change: Students learn changes in one part of a system might cause large changes in another part of the system.	• We completed the first investigation on our student worksheets and then rebuilt the gears for the 2nd investigation. ☐	• We met Bronze. • We graphed a prediction of how many joules of energy we could generate with the new gearing system. • We graphed our measurements. ☐	• We met Silver. • We used our graphs as evidence to explain how changing the gears affected our hand generator's efficiency. ☐	• We met Gold. • We proposed a new experiment to test how another design change to our hand generator would affect its speed and/or efficiency. ☐
2. Student work related to this Practice: In this project, we built and used a model electric car, a joule jeep, to help us test predictions about the energy we could generate with a hand crank and the distance the joule jeep would travel with that energy.				
Developing and using models: Develop and use a model to predict and describe phenomena.	• We built a hand generator model. • We built a joule jeep model. • We made sure our models moved smoothly. ☐	• We met Bronze. • We tested our wire connections. • We zeroed our Energy Meter. • We completed at least one practice energy measurement. ☐	• We met Silver. • We used our hand generator and joule jeep with care to complete all investigations. • We zeroed our Energy Meter in between experiments. ☐	• We met Gold. • We used our models to help us explain how different variables affect our hand generator's performance. ☐
3. Student work related to this Practice: In this project, we planned and carried out an investigation on generating energy with a hand crank. We measured energy with an energy meter and organized our results in a data table.				
Planning and carrying out investigations: Plan an investigation, identify what tools are needed, how measurements are recorded, and how many data are needed to support a claim.	• We gathered the tools we needed in our investigation. ☐	• We met Bronze. • We tested our measurement procedure using the Energy Meter to make sure our results were accurate. ☐	• We met Silver. • We completed all measurements to the best of our ability, redoing measurements as needed. • We completed all data tables. ☐	• We met Gold. • We proposed a new investigation with our hand generator, joule jeep, and Energy Meter. • We outlined what measurements we would make and how much data we would collect. ☐

Notes:

Solar Station

Science
- Transfer of energy
- Conversion of energy
- Scientific investigation
- Systematic observation
- Interpretation of evidence

Technology
- Constructing models
- Product design
- Evaluating

Engineering
- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics
- Applications of angles, ratios, and proportion
- Informal and formal measuring of distance/time/speed/work
- Graphing

Vocabulary
- Current
- Perpendicular to
- LEGO® Solar Panel
- Voltage

Other Materials Required
- A 60W incandescent light bulb, high performance halogen emitters or any other light source that emits a high amount of IR spectra > 800 nm
- Lamp with parabolic reflector
- Ruler or measuring tape
- Aluminium foil

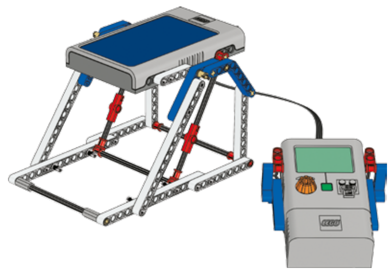
Connect

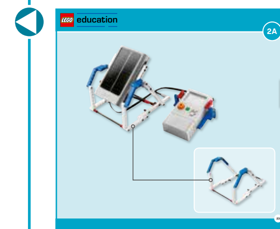
Solar panels have the ability to convert solar energy into electrical energy. They are used to generate electricity for large utility grids, for satellites in space and in isolated locations for small communities or single homes.

Now build the solar station and investigate its ability to generate power.

Construct

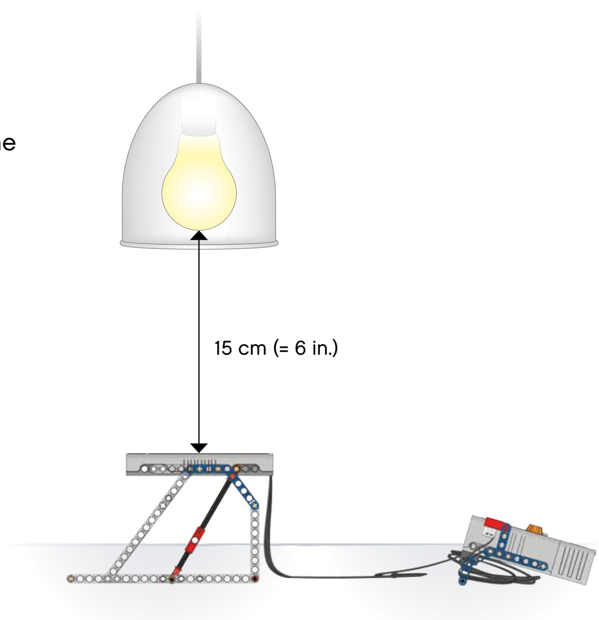
Build the Solar Station
(building instructions booklets 2A and 2B, to page 30, step 15)





- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing

Test Setting
- Position the solar station at a distance of 15 cm (= 6 in.) from the light source
- A 60W incandescent light bulb, high performance halogen emitters or any other light source that emits a high amount of IR spectra > 800 nm.
- Place the Solar Panel under the center of the light source. Optimally the lamps diameter should cover the LEGO® Solar Panel and have a parabolic reflector
- To help students measure the distance of the bulb in the lamp to the Solar Panel, it is helpful to make a mark on the lamp casing, level with the center of the light bulb



Warning!
Heat can damage the Solar Panel. Keep a distance of at least 8 cm (= 3 in.) from the Solar Panel to the light source at all times. Make sure students handle light bulbs with great care!

Contemplate

Changing Angles
The task requires students to investigate how changing the angle of the Solar Panel to the light source will affect the average voltage (V) and average current (A) readings.

First, have students predict the average voltage and current of the solar station when positioned perpendicular to the light source (see opposite) at a distance of 15 cm (= 6 in.).

Then, have students investigate the average voltage and current of the solar station when positioned horizontally. Have them read and record their findings.

Make sure students let the Energy Meter units settle before carrying out the readings.

Next, have students follow the same procedure for the solar station in a diagonal position and a vertical position to the light source (see opposite).

Findings will vary depending on the light source used, the amount of surrounding light in the room and the color of the surface where the solar station is placed. Students will see that maximum power is produced when the incident light beam is perpendicular to the Solar Panels surface.

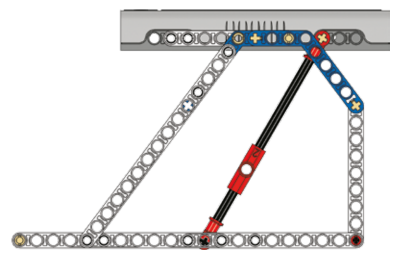
Have students reflect on their investigations by asking questions such as:

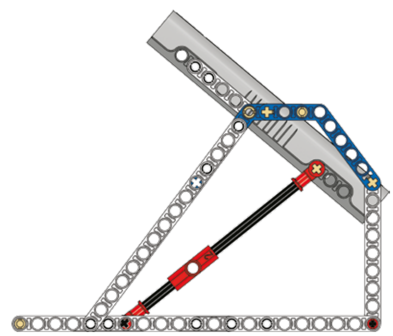
- Which factors did you base your predictions on?
- Can you explain your findings?
- Can you identify a pattern or trend in the findings?

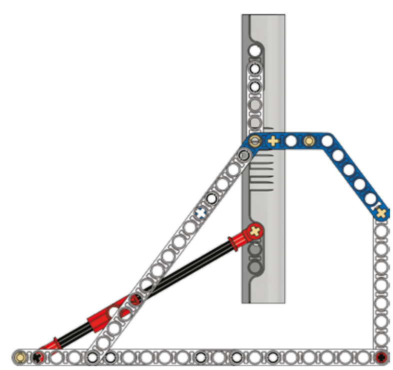
The intensity of the light is at a maximum when the light source is perpendicular to the Solar Panel. As the intensity of light on the surface of the Solar Panel decreases, the voltage, and in particular the current, also decreases.

- How did you make sure that your findings were scientifically valid?

Students need to investigate several times to make sure findings are consistent, that the solar station always stays in the same position and at the same distance from the light source.


Horizontal


Diagonal


Vertical

Hint
Reset the Energy Meter before each investigation.

Hint
The Energy Meter display must show an input reading of more than 2.0 V to show readings on the display.

Continue

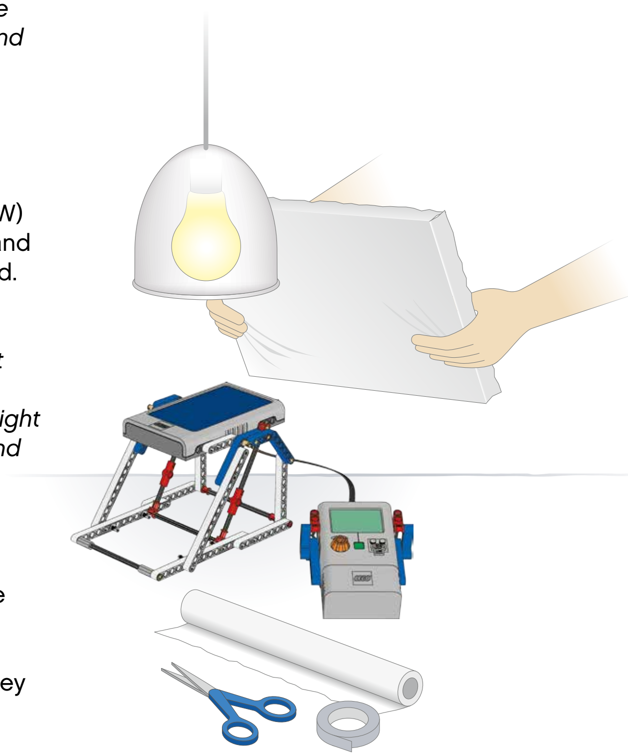
Identifying Variables
Have students identify and write down at least three variables, explaining clearly how these affect the solar station's efficiency.

Some factors could include the size of the area exposed (e.g. partially covering some of the solar station), the light source conditions and the distance to the light source.

Optimizing Variables
Based on the variables students have identified, have them optimize the solar station to maximize the amount of power (W) produced. Have students record findings and describe which variables have been altered.

We suggest increasing the wattage of the lamp; one could also use a mirror to reflect the light onto the solar station and another underneath the solar station to reflect the light back. Instead of a mirror, wrap tin foil around the lid of the basis set as a reflector.

Optional
Have students simulate different weather and landscape situations to investigate the increase or decrease in the solar station's ability to generate power. Have students describe their simulations, the setup and key measurements.



Hint
Reset the Energy Meter before each investigation.

Hint
You can simulate clouds by covering the solar station with tissue paper or other light-absorbent materials.

Solar Station

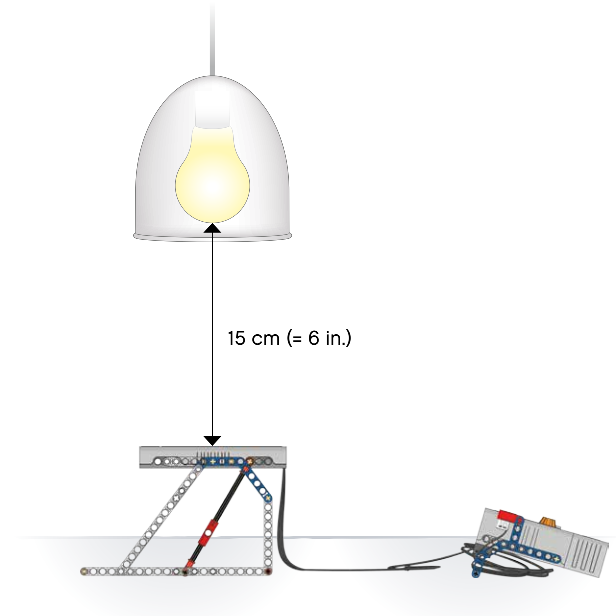
Name(s):

Date and subject:

Build the Solar Station

(building instructions booklets 2A and 2B, to page 30, step 15)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing
- Position the LEGO® Solar Panel under the center of the light source

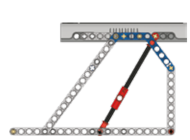
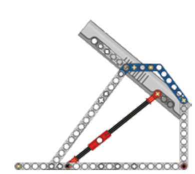
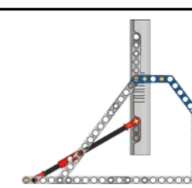


Changing Angles

First, predict the average voltage (V) and the average current (A) readings of the solar station when positioned perpendicular to the light source at a distance of 15 cm (= 6 in.). Remember to reset the Energy Meter before each investigation.

Then, investigate the average voltage and current of the solar station in this horizontal position. Make sure to let the Energy Meter units stabilize before carrying out the readings. Read and record your findings.

Next, follow the same procedure for the solar station in a diagonal position and a vertical position to the light source.

	 **Horizontal**	 **Diagonal**	 **Vertical**
My Prediction of V	(V)	(V)	(V)
My Prediction of A	(A)	(A)	(A)
My Average Findings of V	(V)	(V)	(V)
My Average Findings of A	(A)	(A)	(A)

Identifying Variables

Identify and write down at least three variables, explaining clearly how these affect the efficiency of the solar station.

Optimizing Variables

Based on the variables identified, optimize the solar station to maximize the power generated. Explain which variables are altered, their effect and record findings. Note them on this worksheet and show the set up, e.g. by taking a photograph or by sketching. Remember to reset the Energy Meter before each investigation.

Solar Station

Name(s): ______________________ **Date:** ______________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a solar station and tested how the angle of the solar panel affected the amount of energy we collected from a light source.				
Structure and function: The way in which an object is shaped determine many of its properties and functions.	• We built our solar station. • We completed test measurements of voltage (V) and current (A) with our Energy Meter. ☐	• We met Bronze. • We completed all predictions and measurements for the three solar station angles. ☐	• We met Silver. • We clearly explained how the angle of our structure affected our solar station's efficiency. ☐	• We met Gold. • We used observations and conclusions about our solar station's structure to help us invent ways to optimize our solar station. ☐
2. Student work related to this Practice: In this project, we identified variables that affected the amount of energy we could generate with our solar station. We asked ourselves and classmates questions about these variables to help us optimize our solar station.				
Asking questions and defining problems: Ask questions to determine relationships between independent and dependent variables.	• We reviewed the predictions and measurements in our data table. • We discussed our findings with classmates. ☐	• We met Bronze. • We asked ourselves and our classmates questions about the variables we tested. • We asked questions about variables we did not yet test. ☐	• We met Silver. • We used our questions and discussion to help us determine relationships between independent and dependent variables in our experiments. ☐	• We met Gold. • We used our questions and discussions to help us invent ideas to optimize our solar station. ☐
3. Student work related to this Practice: In this project, we communicated our investigation to make an optimized solar station with words and a photo or sketch.				
Obtaining, evaluating, and communicating information: Integrate qualitative and/ or quantitative information in written text with visual displays to clarify claims and findings.	• We explained with words what we did to optimize our solar station. ☐	• We met Bronze. • We communicated what variables we changed and their effect. • We attached a photograph or a sketch of our optimized solar station. ☐	• We met Silver. • Our explanation clearly refers to features in our photograph or sketch of the set-up we used. • Our photo and/or sketch shows our set up. ☐	• We met Gold. • We attached multiple photos and/or sketches to more clearly communicate what we did to create an optimized solar station. ☐

Notes:

Wind Turbine

Science
- Storage of energy
- Conversion of energy
- Scientific investigation

Technology
- Product design
- Constructing models
- Evaluating

Engineering
- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics
- Informal and formal measuring of distance/time/speed/work
- Reading, predicting, and interpreting data

Vocabulary
- Efficiency
- Power
- Voltage
- Wattage

Other Materials Required
- Adhesive tape
- Fan with an effect of at least 40 W
- Ruler or measuring tape

Connect

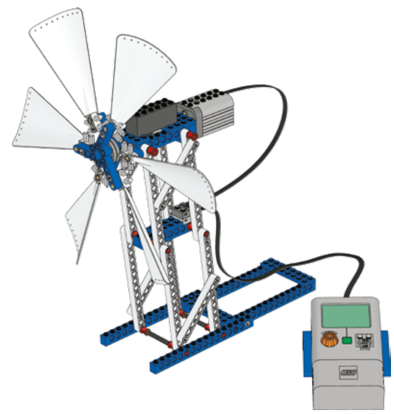
Wind turbines have the ability to convert the wind's kinetic energy into electrical energy. They are used to generate electricity for large utility grids and in isolated locations, such as rural farms.

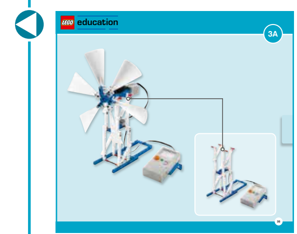
Now build the wind turbine and investigate its ability to generate power.

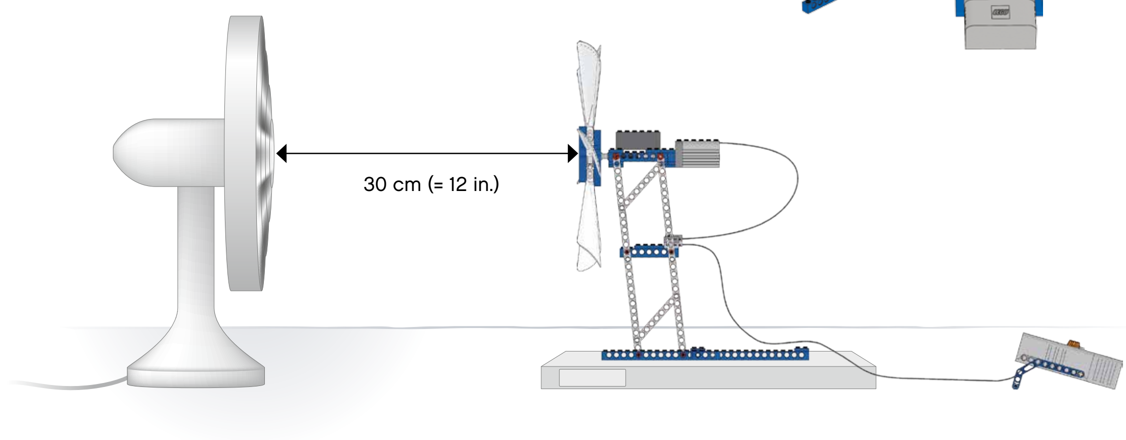
Construct

Build the Wind Turbine
(building instructions booklets 3A and 3B, to page 43, step 18)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing





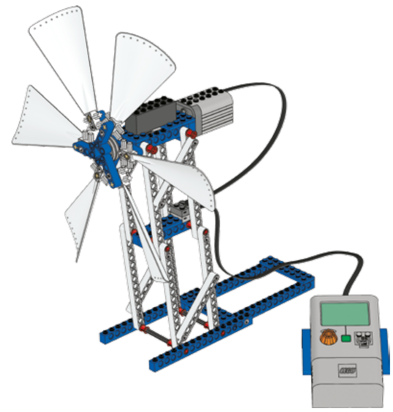


Test Setting

- Align the center of the fan to the center of the wind turbine with a distance of 30 cm (= 12 in.) between them
- Choose a suitable power setting on the fan that makes the wind turbine rotate at an adequate speed and where the Energy Meter's display shows more than 2.0 V on the input reading. The fan must have an effect of at least 40 W
- To find the optimal set up, look at the Energy Meter readings as an indicator of which position generates the most power
- Stability is important; one could choose to use adhesive tape or books to hold the wind turbine in place
- Students can gently 'turn' the blades to get the wind turbine started if needed

Warning!
Fans are potentially dangerous.
Make sure that students handle them with great care!
Ensure that students turn the fan off when changing the number of blades during the activity.

Contemplate



Six Blades and Changing the Distance
The task requires students to investigate the performance of the wind turbine at different settings and to read and record the average voltage (V) and the average power (W) generated.

First, have students predict the voltage and power generated by the wind turbine at a distance of 30 cm (= 12 in.).

Then, have students investigate and read the average voltage and average power generated by the wind turbine. Have them read and record their findings.

Next, have students turn off the fan and change the distance to 15 cm (= 6 in.). Follow the same procedure as described above.

Findings will vary; students will see that power increases when the wind turbine is moved closer to the wind source.

Have students reflect on their investigations by asking questions such as:
- Which factors did you base your predictions on?
- Can you explain your findings?
- Can you identify a pattern or trend in the findings?

The closer the wind source is to the wind turbine, the more power that is generated.

- How did you make sure that your findings were scientifically valid?

Students need to investigate several times to make sure findings are consistent and that the wind turbine stays in the same position and at the same distance from the fan.

Did you know?
Wind turbines can rotate around both horizontal and vertical axis. Horizontal-axis wind turbines (HAWT) are most commonly used.

Hint
Reset the Energy Meter before each investigation.

Continue

Three Blades and Changing the Distance
(building instructions booklets 3A and 3B, to page 44, step 1).

The task requires students to investigate the performance of the wind turbine at different settings and to read and record the average voltage (V) and the average power (W) generated.

First, have students predict the voltage and power generated by the wind turbine at a distance of 30 cm (= 12 in.).

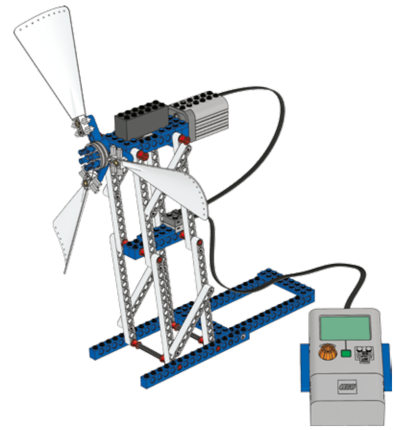
Then, have students investigate and read the average voltage and average power generated by the wind turbine. Have them read and record their findings.

Next, have students turn off the fan and change the distance to 15 cm (= 6 in.). Follow the same procedure as described above.

Findings will vary; students will see that power increases when the wind turbine is moved closer to the wind source. Students will find that the wind turbine with six blades generates more power.

Identifying Variables
Have students identify and write down at least three variables, explaining clearly how these affect the wind turbine's efficiency.

Some factors could include the effect of changing the number of blades used, the angle between the center of the fan and wind turbine and the force of the wind. The efficiency of the E-Motor plays a major role in the overall efficiency of the wind turbine.



Hint
Have students turn off the fan before changing the number of blades on the wind turbine.

Hint
Reset the Energy Meter before each investigation.

Optional
Have students simulate different landscapes to investigate the increase or decrease in the wind turbine's ability to generate power. You can simulate a landscape feature by e.g. placing a book between the fan and the wind turbine.

Have students describe their simulations, the setup and key measurements, e.g. the height and the distance between the fan and the wind turbine.

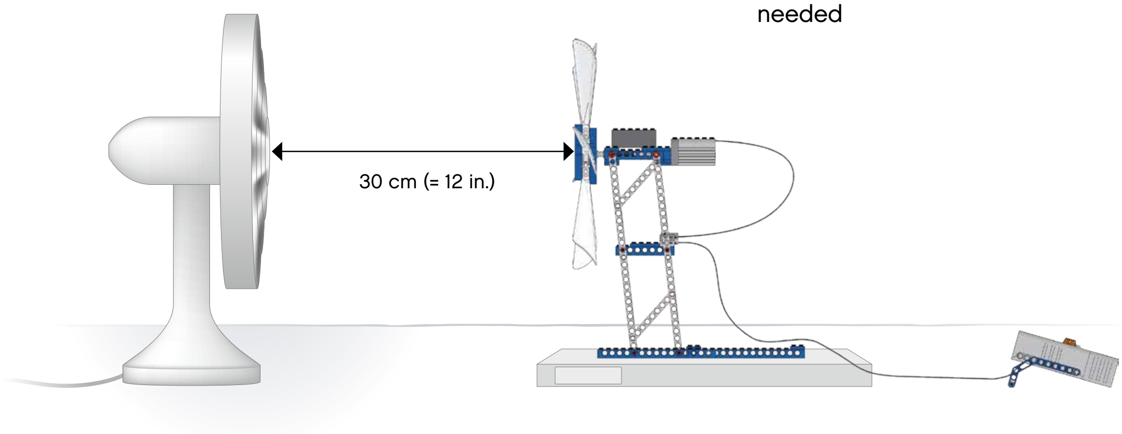
Wind Turbine

Name(s): ______________________ **Date and subject:** ______________________

Build the Wind Turbine

(building instructions booklets 3A and 3B, to page 43, step 18)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing
- Align the center of the fan to the center of the wind turbine
- Choose a suitable power setting on the fan that makes the wind turbine rotate at an adequate speed and where the Energy Meters display shows more than 2.0 V on the input reading.
- Gently 'turn' the blades to get the wind turbine started if needed

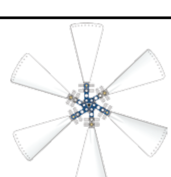


Six Blades and Changing the Distance

First, predict the voltage (V) and power (W) generated by the wind turbine at a distance of 30 cm (= 12 in.).

Then, investigate and read the average voltage and average power generated by the wind turbine. Read and record your findings. Remember to reset the Energy Meter before each investigation.

Next, turn off the fan and change the distance to 15 cm (= 6 in.). Follow the same procedure as described above.

	**30 cm (= 12 in.)**		**15 cm (= 6 in.)**	
My Prediction	(V)	(W)	(V)	(W)
My Average Findings	(V)	(W)	(V)	(W)

Three Blades and Changing the Distance

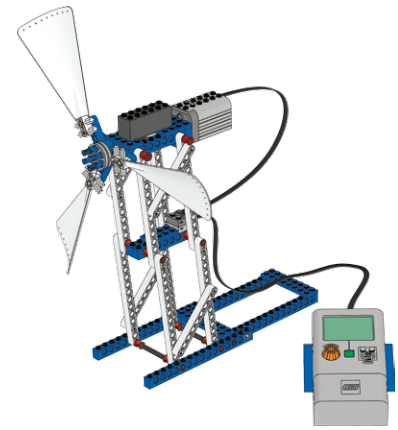
(building instructions booklets 3A and 3B, to page 44, step 1)

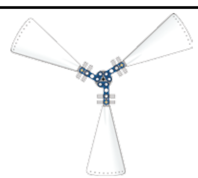
Turn off the fan and remove three blades from the wind turbine.

First, predict the voltage (V) and power (W) generated by the wind turbine at a distance of 30 cm (= 12 in.).

Then, investigate and read the average voltage and average power generated by the wind turbine. Read and record your findings.
Remember to reset the Energy Meter before each investigation.

Next, turn off the fan and change the distance to 15 cm (= 6 in.).
Follow the same procedure as described above.



	**30 cm (= 12 in.)**		**15 cm (= 6 in.)**	
My Prediction	(V)	(W)	(V)	(W)
My Average Findings	(V)	(W)	(V)	(W)

Identifying variables

Identify and write down at least three variables, explaining clearly how these affect the efficiency of the wind turbine.

Wind Turbine

Name(s): ______________________ **Date:** ______________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we investigated how much power is transferred through our wind turbine at different distances and with different blade designs.				
Energy and matter: Flows, cycles, and conservation: Tracking energy in and out of a system helps understand the system's possibilities and limitations.	• We predicted voltage and power for our wind turbine at a distance of 30 cm. • We measured voltage and power for our wind turbine at 30 cm. ☐	• We met Bronze. • We used our first experiment to make our predictions for 15 cm. • We completed our measurements for 15 cm. ☐	• We met Silver. • We used our observations from the distance experiments to make our predictions for the turbine with 3 blades. • We completed our 3 blade turbine experiment. ☐	• We met Gold. • We proposed a procedure for a new turbine power experiment that investigates other variables (such as fan angle or fan speed). ☐
2. Student work related to this Practice: In this project, we built a wind turbine to test our predictions about how different factors affect the power we produced from a fan.				
Developing and using models: Develop and use a model to predict and describe phenomena.	• We built our turbine complete with E Motor and wires to our Energy Meter. • We tested our turbine to make sure it moved smoothly. ☐	• We met Bronze. • We carefully placed our turbine the distance from the fan. • We tested the turbine to ensure it generated more than 2.0 Volts on our Energy Meter. ☐	• We met Silver. • We used our wind turbine model with care to test predictions and complete all investigations. • We zeroed our Energy Meter in between experiments. ☐	• We met Gold. • We used our models to help us explain how different variables affect our wind turbine's performance. ☐
3. Student work related to this Practice: In this project, we identified variables and explained how those variables affected our wind turbine's efficiency.				
Constructing explanations: Construct a scientific explanation based on valid and reliable evidence obtained from student's own experiments.	• Our explanation for how different variables affected the wind turbine's efficiency referred to what we discovered in our experiment. ☐	• We met Bronze. • We used numbers from our experiment to support our ideas. ☐	• We met Silver. • We explained how three different variables affect the wind turbine's efficiency. ☐	• We met Gold. • We shared our explanation and evidence with classmates. • We revised our explanation to make it more understandable. ☐

Notes:

Hydro Turbine

Science
- Storage of energy
- Conversion of energy
- Scientific investigation

Technology
- Product design
- Graphing
- Selecting appropriate methods for estimating and measuring
- Constructing models
- Evaluating

Engineering
- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics
- Informal and formal measuring of distance/time/speed/work

Vocabulary
- Joules
- Water pressure

Other Materials Required
- Adhesive tape
- Enough water pressure to read at least 2.0 V on the Energy Meter input reading
- Graph paper
- Stopwatch or timer
- Paper or cloth towels to dry LEGO® elements

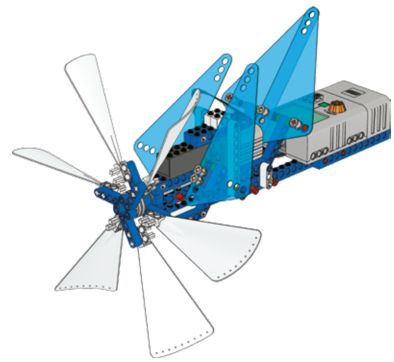
Connect

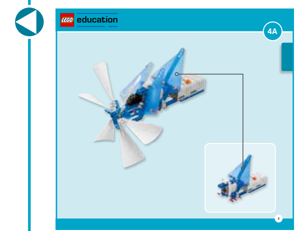
Hydro turbines have the ability to convert the kinetic energy of moving water into electrical energy. They are used to generate electricity for large utility grids and in isolated locations for small communities or for single homes.

Now build the hydro turbine and investigate its ability to generate power.

Construct

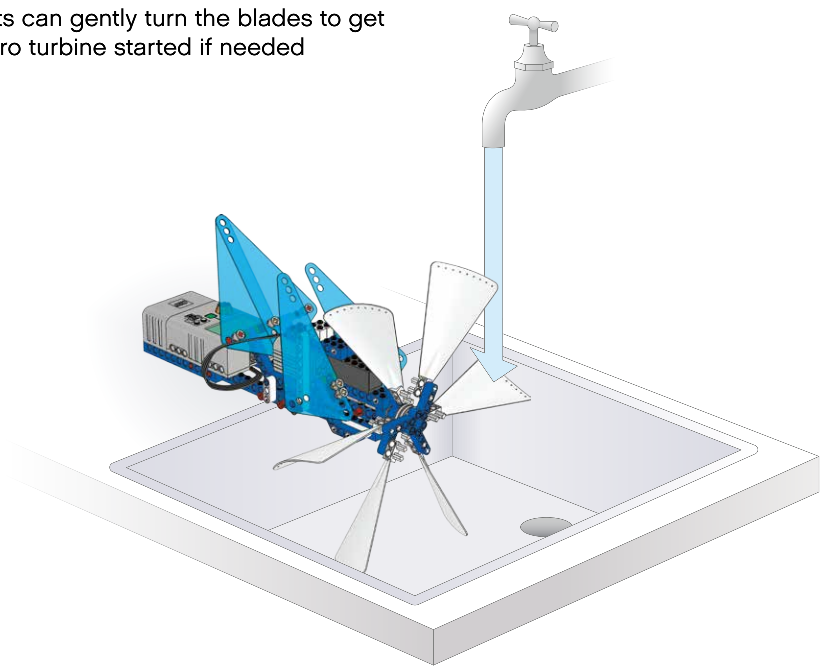
Build the Hydro Turbine
(building instructions booklets 4A and 4B, to page 20, step 30)





- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules reading to zero before testing

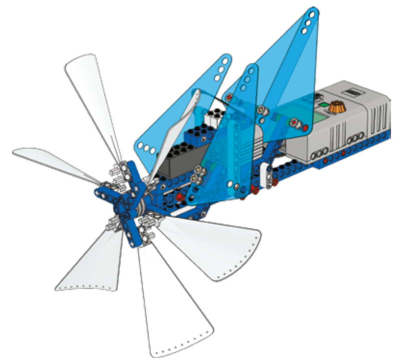
Test setting
- Position the hydro turbine at an appropriate distance from the tap
- Choose a suitable, constant water pressure that shows at least 2.0 V on the Energy Meter's input reading
- To find the optimal set up, look at the Energy Meter readings as an indicator of which position generates the most power
- When the pressure point is found, mark the tap handles position with a piece of adhesive tape
- Have paper or cloth towels close at hand to dry LEGO® elements
- Students can gently turn the blades to get the hydro turbine started if needed



Warning!
Make sure that the Energy Meter and the E-Motor are protected as best you can from water spray, they are not waterproof. Additional protection from a plastic bag or cling wrap might be appropriate.

Contemplate

Accumulating Joules
The task requires students to investigate how many joules (J) the hydro turbine can accumulate after a time period of 120 seconds.



First, have students predict how many joules the hydro turbine will accumulate after a time period of 120 seconds at 20 second intervals.

Then, have students graph their prediction in a system of coordinates of how many joules the hydro turbine will accumulate after a time period of 120 seconds at 20 second intervals.

Next, have students investigate how many joules they can accumulate after a period of 120 seconds. Have them read and record their findings at 20 second intervals and have them graph their findings in the same system of coordinates as their prediction.

Before taking any readings, make sure students let the hydro turbine run for a while to pick up speed.

Findings will vary depending on the water power device available, students will see that the amount of joules accumulated is proportional to the water pressure and time period used.

Have students reflect on their investigations by asking questions such as:
- Which factors did you base your predictions on?
- Can you explain your findings?
- Can you identify a pattern or trend in the findings?

The amount of joules accumulated is proportional to the water pressure and time period.

- How did you make sure that your findings were scientifically valid?

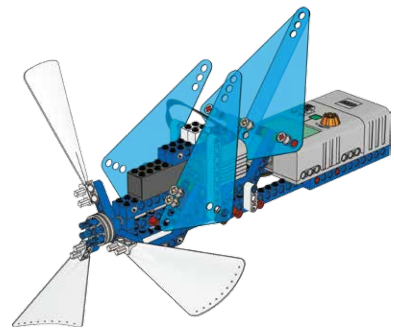
Students need to investigate several times to make sure findings are consistent, that the hydro turbine turns either clockwise or counter-clockwise each time, that the water hits the blades in the same spot in every investigation and that the hydro turbine always stays in the same position and at the same distance from the water supply.

Hint
The Energy Meter display must show more than 2.0 V on the input reading.

Hint
Reset the Energy Meter before each investigation.

Continue

Changing the Number of Blades
(building instructions booklets 4A and 4B, to page 22 step 2)



The task requires students to investigate how many joules (J) the hydro turbine can accumulate after a time period of 120 seconds, with only three blades attached.

First, have students predict how many joules the hydro turbine will accumulate after a time period of 120 seconds at 20 second intervals.

Then, have students graph their prediction in a system of coordinates of how many joules the hydro turbine will accumulate after a time period of 120 seconds at 20 second intervals.

Next, have students investigate how many joules they can accumulate after a period of 120 seconds. Have them read and record their findings at 20 second intervals and have them graph their findings in the same system of coordinates as their prediction.

Before taking any readings, make sure students let the hydro turbine run for a while to pick up speed.

Findings will vary depending on the water power device available, students will see that the amount of joules accumulated is proportional to the water pressure and time period used. Students will also see that a lesser amount of joules are accumulated when the hydro turbine only has three blades attached.

Identifying Variables
Have students identify and write down at least three variables, explaining clearly how these affect the hydro turbine's efficiency.

Some factors could include the effects of changing the diameter of the hydro turbine, the area and number of blades used, the angle and position at which the blades catch the flow of water, and the condition of the water flow.

Did you know?
The power available from any water power device depends on three variables: the height that the water supply is above the turbine, also called the head, the flow rate and gravity.

Hint
Reset the Energy Meter before each investigation and remember to keep the same water pressure as before.

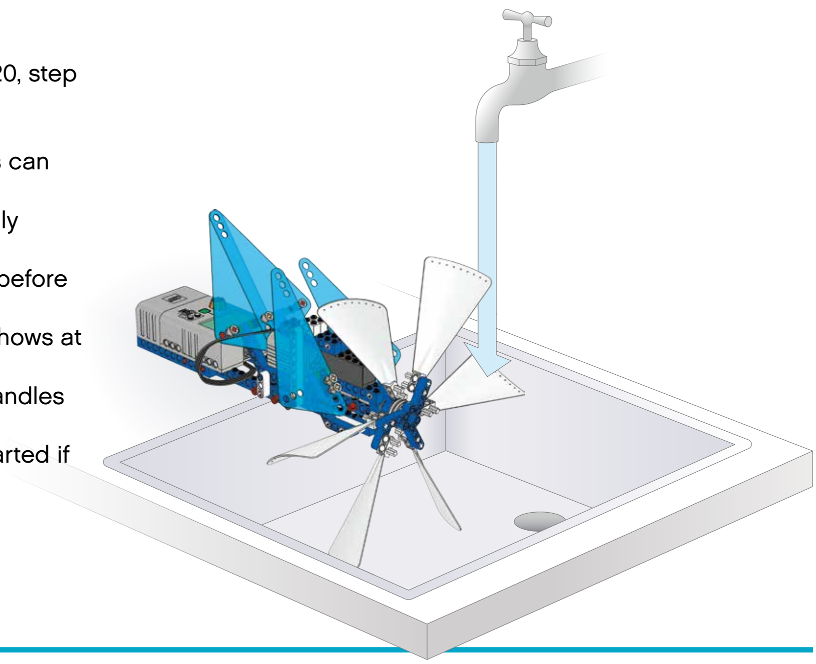
Hydro Turbine

Name(s): ______________________ **Date and subject:** ______________________

Build the Hydro Turbine

(building instructions booklets 4A and 4B, to page 20, step 30)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing
- Choose a suitable, constant water pressure that shows at least 2.0 V on the Energy Meters input reading
- When the pressure point is found, mark the tap handles position with a piece of adhesive tape
- Gently turn the blades to get the hydro turbine started if needed

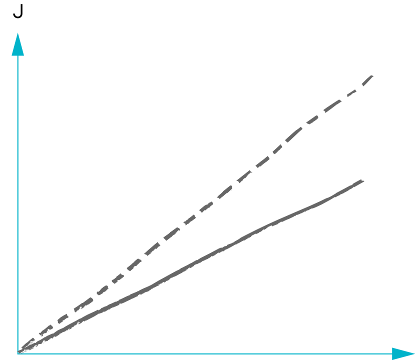


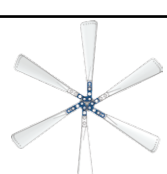
Accumulating Joules

First, predict how many joules (J) the hydro turbine will accumulate after a time period of 120 seconds (sec.) at 20 second intervals.

Then, graph your prediction in a system of coordinates, as illustrated opposite.

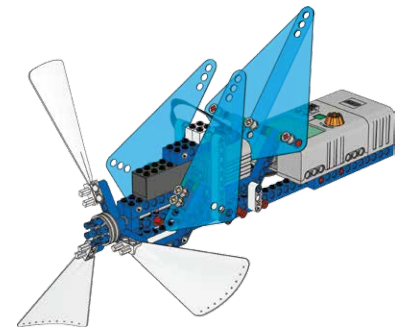
Next, investigate how many joules can be accumulated after a period of 120 seconds. Read and record your findings at 20 second intervals. Graph your findings in the same system of coordinates as your prediction. Remember to reset the Energy Meter before each investigation.



	20 sec.	40 sec.	60 sec.	80 sec.	100 sec.	120 sec.
My Prediction	(J)	(J)	(J)	(J)	(J)	(J)
My Findings	(J)	(J)	(J)	(J)	(J)	(J)

Changing the Number of Blades

(building instructions booklets 4A and 4B, to page 22, step 2)

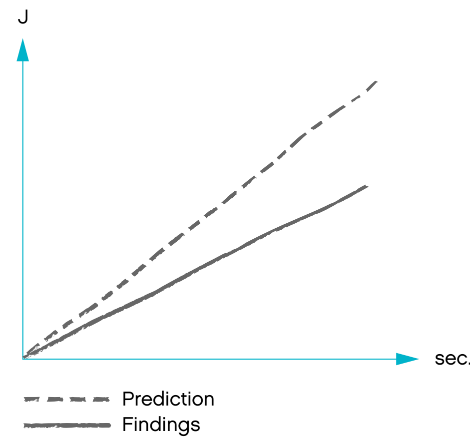


Change the number of blades on the hydro turbine by removing three blades and follow the same procedure as previously. Keep the same water pressure as before.

First, predict how many joules (J) the hydro turbine will accumulate after a time period of 120 seconds (sec.) at 20 second intervals.

Then, graph your prediction in a system of coordinates, as illustrated opposite.

Next, investigate how many joules can be accumulated after a period of 120 seconds. Read and record your findings at 20 second intervals. Graph your findings in the same system of coordinates as your prediction. Remember to reset the Energy Meter before each investigation.



	20 sec.	40 sec.	60 sec.	80 sec.	100 sec.	120 sec.
My Prediction	(J)	(J)	(J)	(J)	(J)	(J)
My Findings	(J)	(J)	(J)	(J)	(J)	(J)

Identifying Variables

Identify and write down at least three variables, explaining clearly how these affect the efficiency of the hydro turbine.

Hydro Turbine

Name(s): ______________________ **Date:** ______________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we used scale and proportions to help us make predictions in our experiments and to help us explain how different variables affect our hydro turbine's efficiency.				
Scale, proportion, and quantity: Use proportional relationships to gather information about the magnitude of properties.	• We tested our hydro turbine's functionality. • We observed test measurements when the turbine was properly connected to the Energy Meter. ☐	• We met Bronze. • We used proportions (such as twice as much time will yield twice as much energy) to make our predictions in the six blade experiment. ☐	• We met Silver. • We used a proportional relationship to make our predictions for the three blade experiment. ☐	• We met Gold. • We labeled the line on our graphs with the proportions we observed (number of joules per second) in both experiments. ☐
2. Student work related to this Practice: In this project, we created graphs to compare our predictions with our findings in our hydro turbine experiments. We also used our graphs to help see how different variables affected our turbine's efficiency.				
Analyzing and interpreting data: Construct, analyze, and interpret graphical displays of data.	• We created a graph of our predictions in the six blade experiment. • We labeled the independent and dependent axes. ☐	• We met Bronze. • We created a graph for our measurements in the six blade experiment. • We analyzed our data to help us make a prediction in the three blade experiment. ☐	• We met Silver. • We created a graph for our predictions and measurements in the three blade experiment. • We used the analysis of our data to help us explain how the number of blades affects our turbine's efficiency. ☐	• We met Gold. • We used the graphs of our data as a source of information to help us explain how other variables might affect the efficiency of our hydro turbine. ☐
3. Student work related to this Practice: In this project, we identified variables and explained how those variables affected our hydro turbine's efficiency.				
Constructing explanations: Construct a scientific explanation based on valid and reliable evidence obtained from student's own experiments.	• Our explanation for how different variables affected the hydro turbine's efficiency referred to what we discovered in our experiment. ☐	• We met Bronze. • We used numbers from our experiment to support our ideas. ☐	• We met Silver. • We explained how three different variables affect the hydro turbine's efficiency. ☐	• We met Gold. • We shared our explanation and evidence with classmates. • We revised our explanation to make it more understandable. ☐

Notes:

Solar Vehicle

Science
- Transfer of energy
- Storage of energy
- Conversion of energy
- Motion and forces
- Scientific investigation
- Interpretation of evidence

Technology
- Constructing models
- Product design
- Evaluating
- Using mechanisms – gears, wheels and axles

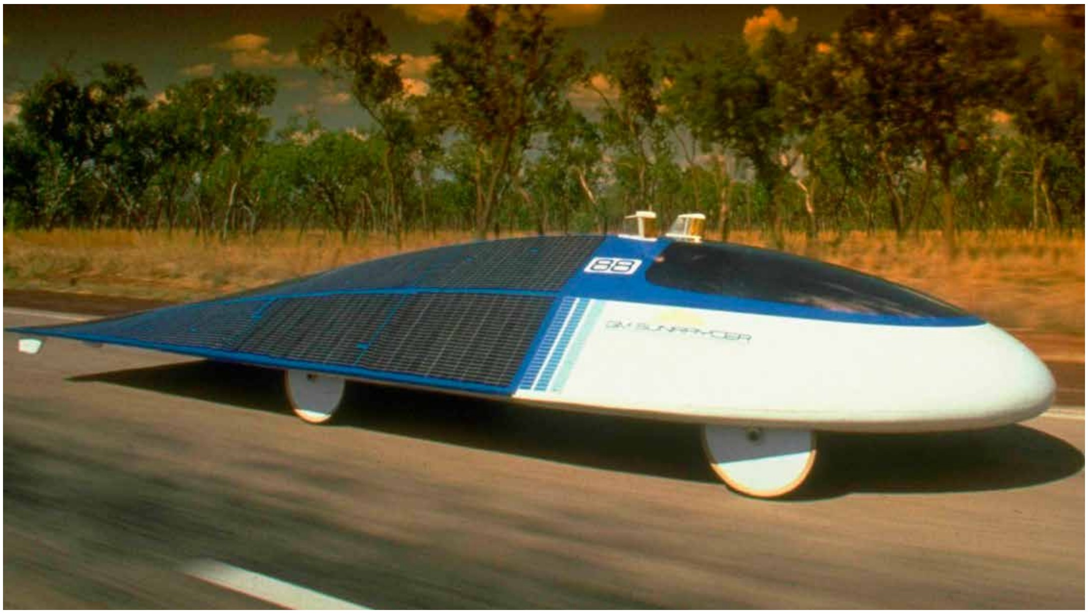
Engineering
- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics
- Informal and formal measuring of distance/time/speed/work
- Selecting appropriate methods for estimating and measuring
- Reading, predicting, and interpreting data

Vocabulary
- Efficiency
- LEGO® Solar Panel
- Speed

Other Materials Required
- A smooth flat track surface at least 150 cm (= 5 ft.) long
- A 60 W incandescent light bulb, high performance halogen emitters or any other light source that emits a high amount of IR spectra > 800 nm
- Lamps with parabolic reflectors
- Masking tape and marker for start and stop line
- Ruler or measuring tape
- Stopwatch or timer

Connect

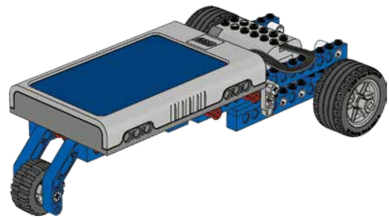


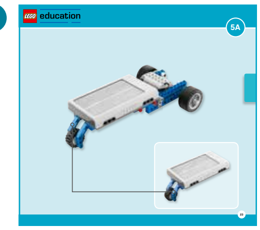
Solar vehicles use the ability of solar panels to convert solar energy into electrical energy. The motor has the ability to convert electrical energy into mechanical energy and move the vehicle.

Now build the solar vehicle and investigate its speed with different gear ratios and wheel size.

Construct

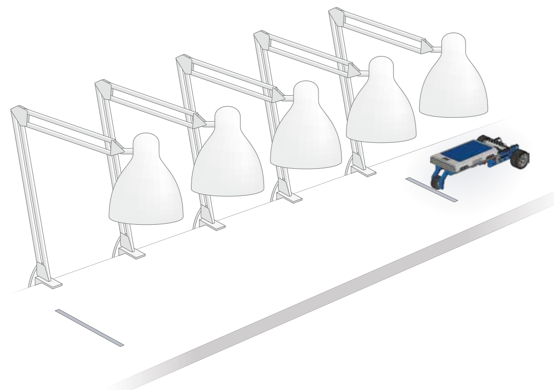
Build the Solar Vehicle
(building instructions booklets 5A and 5B, to page 38, step 24)



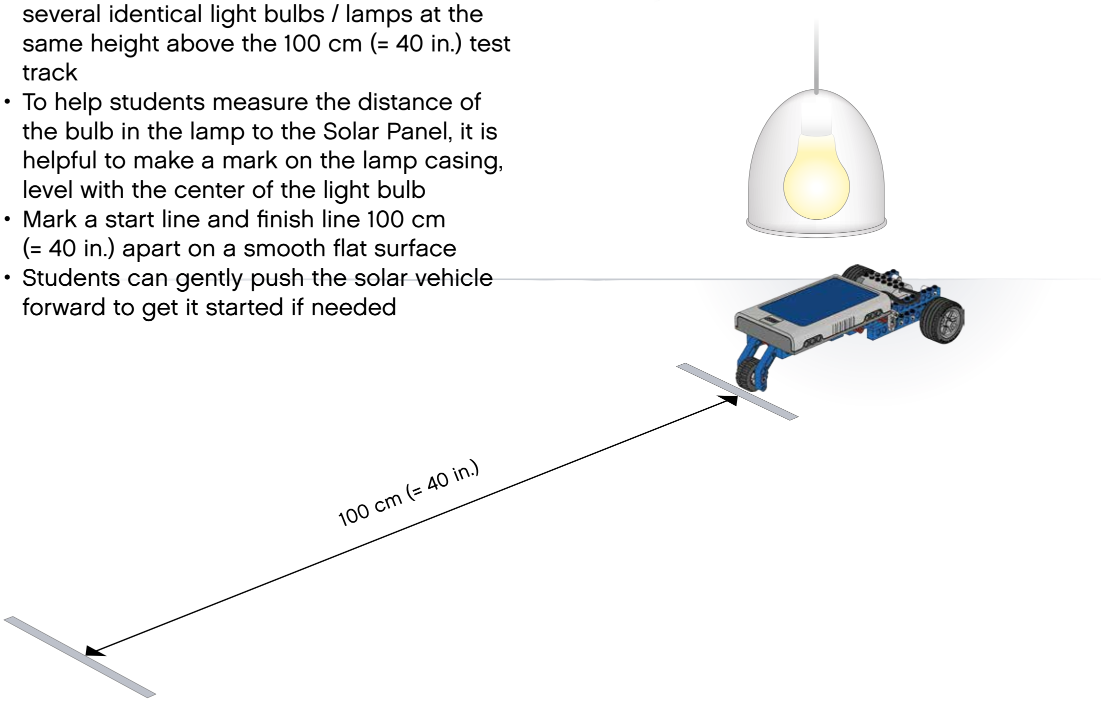


- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together

Test setting



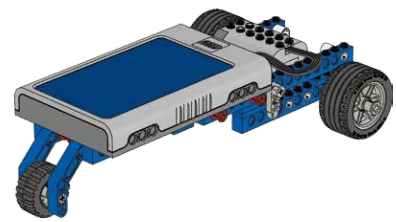
- Position the LEGO® Solar Panel at an adequate distance from the light source
- A 60 W incandescent light bulb, high performance halogen emitters or any other light source that emits a high amount of IR spectra > 800 nm
- Place the Solar Panel under the center of the light source. Optimally the lamps diameter should cover the LEGO Solar Panel and have a parabolic reflector
- To set up an illuminated test track, place several identical light bulbs / lamps at the same height above the 100 cm (= 40 in.) test track
- To help students measure the distance of the bulb in the lamp to the Solar Panel, it is helpful to make a mark on the lamp casing, level with the center of the light bulb
- Mark a start line and finish line 100 cm (= 40 in.) apart on a smooth flat surface
- Students can gently push the solar vehicle forward to get it started if needed



Warning!
Heat can damage the Solar Panel. Keep a distance of at least 8 cm (= 3 in.) from the Solar Panel to the light source at all times. Make sure students handle light bulbs with great care!

Contemplate

Traveling with Different Gear Ratios
The task requires students to investigate the speed of the solar vehicle traveling the track with different gearings and two large rear wheels.



First, have students predict with which speed the solar vehicle will travel the track with a gearing of 5:1.

Then, have students investigate the speed of the solar vehicle traveling the track with a gearing of 5:1. Calculate the speed and record your findings. Use this formula, where speed is measured in meters per second:

$$\textbf{Speed} = \frac{\textbf{Distance traveled}}{\textbf{Time taken}}$$

Findings will vary depending on the light source and the influence of friction.

Next, rebuild the solar vehicle and have students follow the same procedure for the new solar vehicle with a gearing of 3:1. (building instructions booklets 5A and 5B, to page 42, step 4)

Findings will vary, students will see that the solar vehicle with a gearing of 3:1, travels fastest.

Have students reflect on their investigations by asking questions such as:
- Which factors did you base your predictions on?
- Can you explain your findings?
- Can you identify a pattern or trend in the findings?

The 3:1 gearing travels fastest because of the gear ratio.

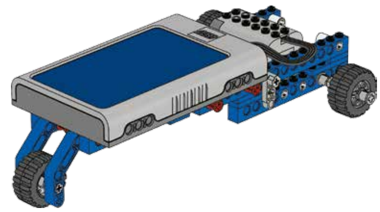
- How did you make sure that your findings were scientifically valid?

Students need to investigate several times to make sure findings are consistent and that the Solar Panel stays in the same position and at the same distance from the light source.

Did you know?
Gear ratio can be found by comparing the number of teeth on the gears.

Continue

Traveling with Smaller Wheels
(building instructions booklets 5A and 5B, to page 44 step 6)
The task requires students to investigate the speed of the solar vehicle traveling the track with a gearing of 3:1 and with two small rear wheels.



First, have students predict with which speed the solar vehicle will travel the track with a gearing of 3:1 and three identical small wheels.

Then, have students investigate the speed of the solar vehicle traveling the track with a gearing of 3:1 and three identical small wheels. Calculate the speed and record your findings.

Findings will vary depending on the light source and friction.

Next, have students look carefully at their findings and compare this new arrangement of the solar vehicle to the prior test findings, where the solar vehicle had a 3:1 gearing and two larger rear wheels.

Findings will vary, but the solar vehicle with the large rear wheels will travel the distance fastest, even though the axel speed is the same, due to the larger circumference of the larger wheels.

Identifying Variables
Have students identify and write down at least three variables, explaining clearly how these affect the solar vehicle's efficiency.

Some factors could include the effects of changing the amount of light on the Solar Panel, friction, wheel diameter, balance and changing the weight of the solar vehicle.

Optional
Have students optimize conditions for the solar vehicle.

Did you know?
The circumference of the small wheel is 9.6 cm (= 3 3/4 in.).

The circumference of the large wheel is 13.6 cm (= 5 3/8 in.).

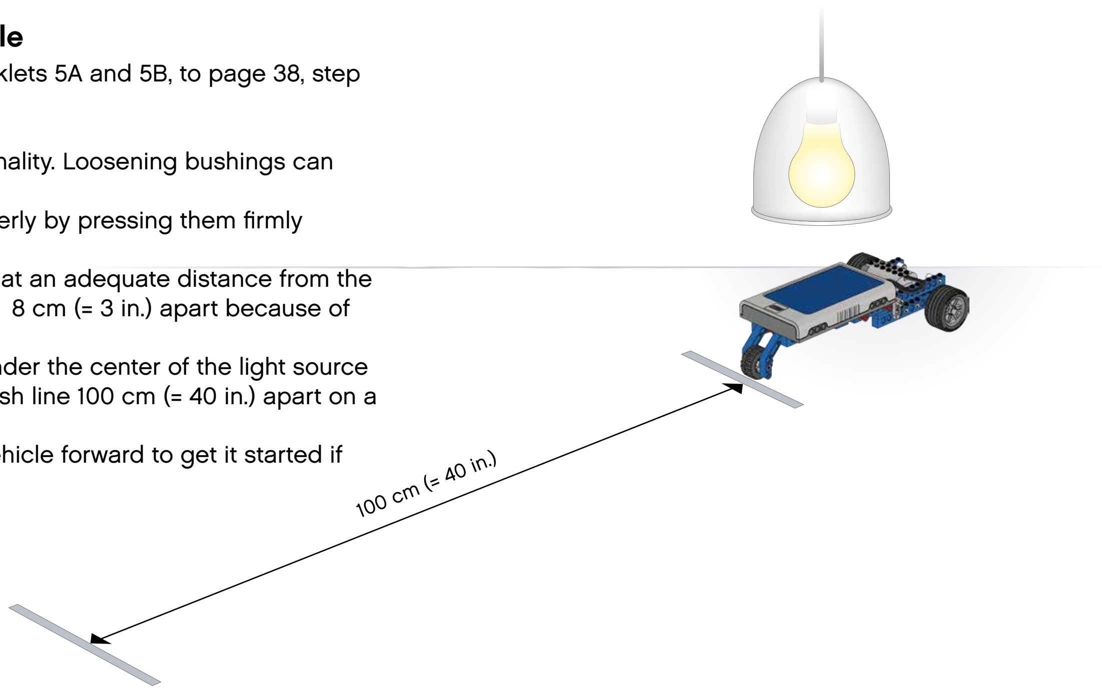
Solar Vehicle

Name(s): ______________________ **Date and subject:** ______________________

Build the Solar Vehicle

(building instructions booklets 5A and 5B, to page 38, step 24)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Position the Solar Panel at an adequate distance from the light source, but at least 8 cm (= 3 in.) apart because of heat
- Place the Solar Panel under the center of the light source
- Mark a start line and finish line 100 cm (= 40 in.) apart on a smooth flat surface
- Gently push the solar vehicle forward to get it started if needed



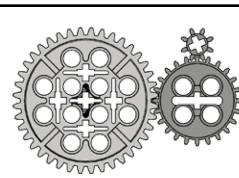
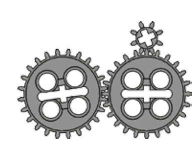
Traveling with Different Gear Ratios

First, predict with which speed the solar vehicle will travel the track with a gearing of 5:1.

Then, investigate with which speed the solar vehicle will travel the track with the gearing of 5:1, where speed is measured in meters per second (m/s), by using this formula:

$$\textbf{Speed} = \frac{\textbf{Distance traveled}}{\textbf{Time taken}}$$

Next, rebuild the solar vehicle and follow the same procedure for the new solar vehicle with a gearing of 3:1. (building instructions booklets 5A and 5B, to page 42, step 4)

		
My Prediction	sec.	sec.
My Findings	sec.	sec.
My Calculations	(m/s)	(m/s)

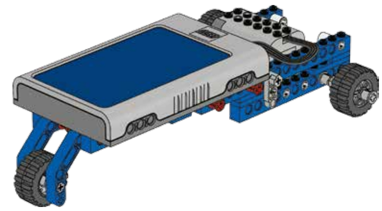
Traveling with Smaller Wheels

(building instructions booklets 5A and 5B, to page 44, step 6)

First, predict with which speed the solar vehicle will travel the track with a gearing of 3:1 and three identical small wheels.

Then, investigate and calculate the speed of the rebuilt solar vehicle.

Next, compare how the rebuilt solar vehicles findings compare to the prior test findings, where the solar vehicle had a 3:1 gearing and two larger rear wheels. Collect your findings below.



		
My Prediction	sec.	sec.
My Findings	sec.	sec.
My Calculations	(m/s)	(m/s)

Look carefully and analyze your findings. Draw a conclusion and write it down.

Identifying Variables

Identify and write down at least three variables, explaining clearly how these affect the efficiency of the solar vehicle.

Solar Vehicle

Name(s): ______________________ **Date:** ______________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we built a solar vehicle and investigated how changes in the vehicle's gears and wheels affected its speed.				
Systems and system models: Systems may have sub-systems and be a part of a larger complex system. Use models to represent systems and their interactions.	• We built our solar vehicle. • We tested our models functionality to make sure it moved smoothly. ☐	• We met Bronze. • We completed our predictions and measurements for the gear ratio experiment. ☐	• We met Silver. • We completed our predictions and measurements for the wheel size experiment. ☐	• We met Gold. • We used the phrases 'system' and 'sub- system' correctly when referring to the gears, wheels, and solar vehicle in our written conclusion. ☐
2. Student work related to this Practice: In this project, we compared the similarities and differences in the data from two experiments. We drew a conclusion from our findings.				
Analyzing and interpreting data: Analyze and interpret data to determine similarities and differences in findings.	• We completed our experiments with two different gear ratios and wheel sizes. ☐	• We met Bronze. • We compared the results from our two gear ratio experiments. • We described the similarities or differences in our conclusion. ☐	• We met Silver. • We compared the results from our two wheel size experiments. • We described the similarities or differences in our conclusion. ☐	• We met Gold. • We compared all of our results. • We drew a conclusion about which had more of an effect on our car: changing wheel size or changing gear ratio. ☐
3. Student work related to this Practice: In this project, we predicted and calculated from measurements the speed of our solar vehicle.				
Using mathematics and computational thinking: Apply mathematical concepts such as ratio and rate to scientific and engineering questions.	• We built and tested 5:1 and 3:1 gear ratios. ☐	• We met Bronze. • We calculated the speed of our solar vehicle in all experiments. ☐	• We met Silver. • We used ratios and rates (speed) in our written conclusion. ☐	• We met Gold. • We used ratios and rates (speed) in our explanation of how different variables affect the efficiency of our solar vehicle. ☐

Notes:

Boat Pulley

Science
- Transfer of energy
- Storage of energy
- Conversion of energy
- Scientific investigation
- Interpretation of evidence

Technology
- Constructing models
- Product design
- Evaluating
- Using mechanisms – pulleys

Engineering
- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics
- Informal and formal measuring of distance/time/speed/work
- Selecting appropriate methods for estimating and measuring
- Reading, predicting, and interpreting data

Vocabulary
- Distance
- Efficiency
- Friction
- Joules
- Load
- Mass
- Work

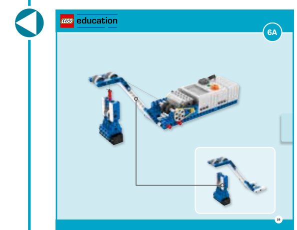
Other Materials Required
- Ruler or measuring tape

Connect

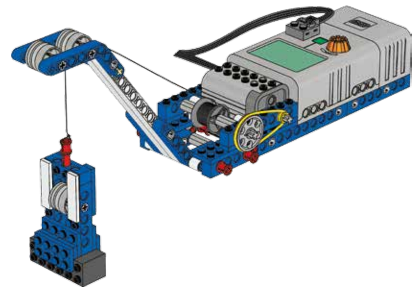
Boat pulleys have the ability to hoist and lower heavy loads with ease using the mechanical advantage in the block and tackle. The amount of power needed can be changed by altering the pulley system.

Now build the boat pulley and investigate the influence of pulley systems on the power needed to lift the load.

Construct

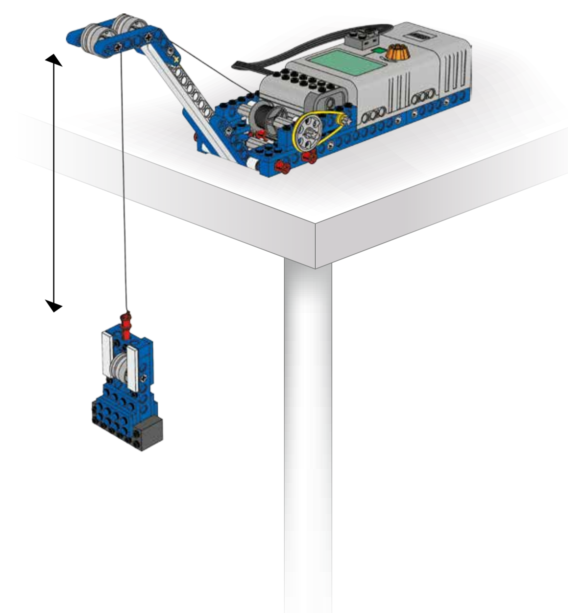


Build the Boat Pulley
(building instructions booklets 6A and 6B, to page 63, step 26).

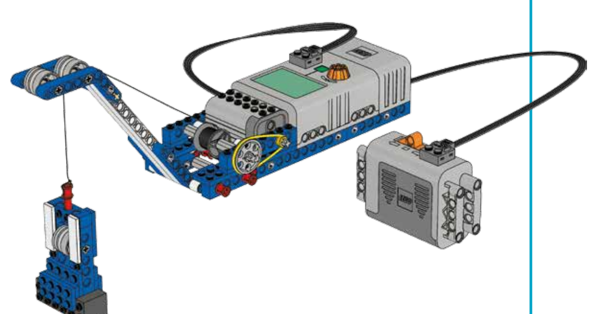


- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together

Test Setting
- Place the boat pulley on a table and let the load hang freely over the side with as much string as possible pulled down

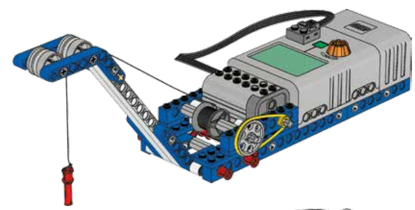


- Charge the boat pulley with a minimum of 50 joules (J)

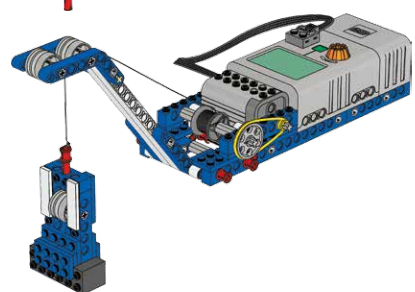


Contemplate

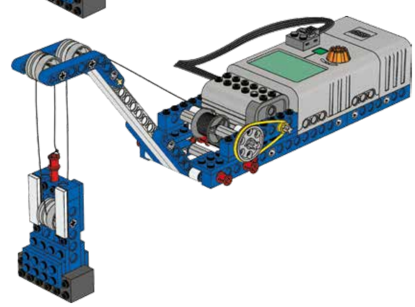
Lifting the Load
The task requires students to investigate the influence of pulley systems on the power (W) needed to lift a given load.



First, have the students predict and investigate how much power the boat pulley needs to lift with the load removed, as shown. Have them read and record their findings.



Then, have the students predict and investigate how much average power the boat pulley needs to lift the load with one fixed pulley. Have them read and record their findings.



Next, rebuild the boat pulley with the load and have students follow the same procedure now with two fixed and one movable pulley.

(building instructions booklets 6A and 6B, to page 64, step 1)

The power the boat pulley uses to lift with the load removed, must be subtracted from the two other findings, in order to compare the pulley systems. Findings will vary; students will see that the pulley system with two fixed and one movable pulley needs significantly less power to lift the load. It has an ideal mechanical advantage of three, meaning that the pulley system under ideal conditions should only use a third of the amount of power needed to lift the load. In reality, the influence of variables such as friction will make the actual mechanical advantage much less.

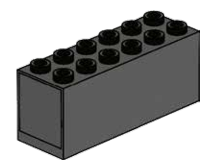
Have students reflect on their investigations by asking questions such as:
- Which factors did you base your predictions on?
- Can you explain your findings?
- Can you identify a pattern or trend in the findings?

An increase in lifting time when using more pulleys is noticeable.

- How did you make sure that your findings were scientifically valid?

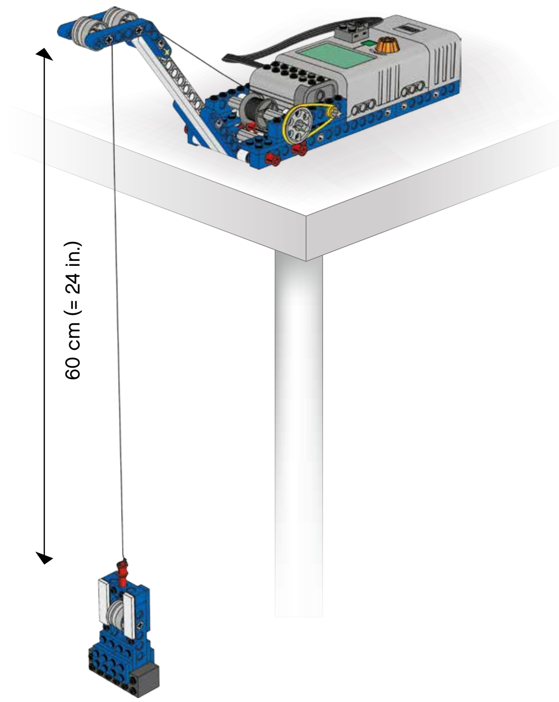
Students need to investigate several times to make sure findings are consistent and make no changes to the boat pulley which could affect its efficiency, e.g. loosening a point of friction.

Did you know?
The LEGO® weight element weighs approximately 53 g.



Continue

Investigating Efficiency
The task requires students to investigate the boat pulley's percentage of efficiency by calculating the ideal amount of work that needs to be applied and by measuring the actual amount of work that needs to be applied to lift the load over a vertical distance of 60 cm (= 24 in.).



First, have students calculate the ideal amount of work needed by using this formula:

Work (J) = Force (N) x Distance (m)

Then, have students investigate the actual amount of work needed by reading the consumption of joules (J) on the Energy Meter display. Have them record their findings.

Next, have students calculate the boat pulley's percentage of efficiency by using this formula:

$$\textbf{Efficiency} = \frac{\textbf{Work done}}{\textbf{Energy used}} \times 100$$

The load weighs approximately 0.068 kg giving a force of approximately 0.67 N and the ideal amount of work the boat pulley needs to apply to lift the load would be:

Work = 0.67 N x 0.6 m
Work = 0.402 J

When investigating how much work the boat pulley actually applies it is essential that students get an accurate joule reading. Findings will vary, though most will find the boat pulley applies approximately 2 J to lift the load, which equals an efficiency percentage of approximately 20%.

$$\textbf{Efficiency} = \frac{\textbf{0.402 J}}{\textbf{2 J}} \times 100$$

Efficiency = 20.1%

This means that approximately 80% of the all the work applied by the boat pulley is lost to friction, heat and other variables.

Hint
Calculate the force using this formula:
F = m x g
F is the force, *m* is the mass, measured in kilogram, and *g* is the proportionality constant, which is 9.8 m/s^2.
One could also use a Newton meter.

Identifying Variables
Have students identify and write down at least three variables, explaining clearly how these affect the boat pulley's efficiency.

Some factors could include the effects of changing the pulley system, pulley wheels and friction.

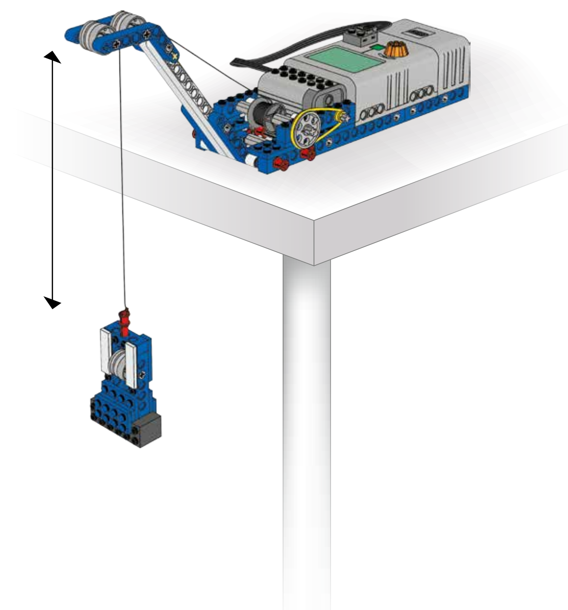
Boat Pulley

Name(s): ______________________ **Date and subject:** ______________________

Build the Boat Pulley

(building instructions booklets 6A and 6B, to page 63, step 26)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Let the load hang with as much string as possible pulled down
- Charge the boat pulley with a minimum of 50 joules (J)



Lifting the Load

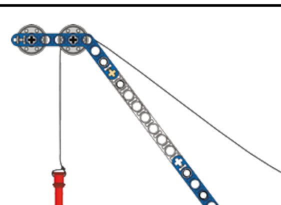
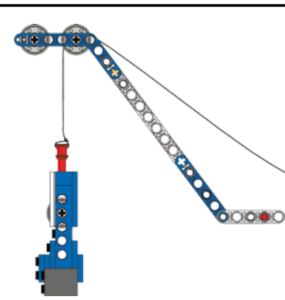
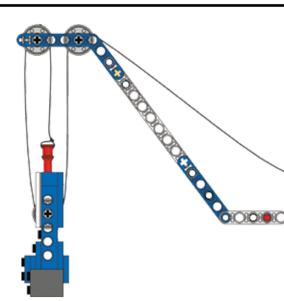
(building instructions booklets 6A and 6B, to page 64, step 1)

First, predict and investigate how much power the boat pulley needs to lift with the load removed. Read and record your findings.

Then, predict and investigate how much average power the boat pulley needs to lift the load with one fixed pulley. Read and record your findings.

Next, rebuild the boat pulley, and predict and investigate the influence on the power needed to lift the load with a new pulley system, now with two fixed and one movable pulley.

The power the boat pulley uses to lift with the load removed, must be subtracted from the two other findings, in order to compare the pulley systems.

			
My Prediction	(W)	(W)	(W)
My Findings	(W)	(W)	(W)

Investigating Efficiency

Investigate the percentage of efficiency of the boat pulley both by calculating the ideal and measuring the actual amount of work that needs to be applied to be able to lift a load over a vertical distance of 60 cm (= 24 in.).

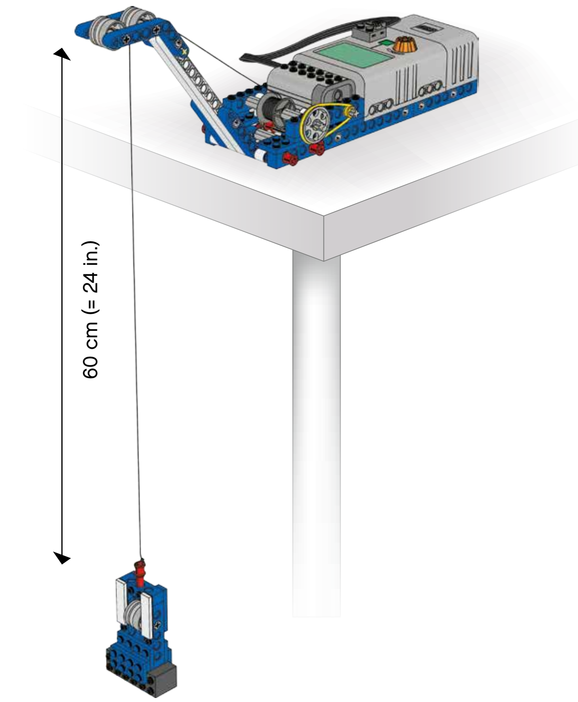
First, calculate the ideal amount of work needed by using this formula:

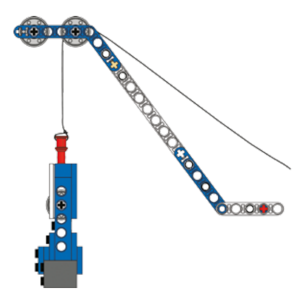
Work (J) = Force (N) x Distance (m)

Then, investigate the actual amount of work needed, by reading the consumption of joules (J) on the Energy Meter display. Record your findings.

Next, calculate the percentage of efficiency of the boat pulley by using this formula:

$$\textbf{Efficiency} = \frac{\textbf{Work Done}}{\textbf{Energy Used}} \times 100$$



	
Ideal amount of work needed (J)	(J)
Actual amount of work needed (J)	(J)
Percentage of efficiency for boat pulley (%)	(%)

Identifying Variables

Identify and write down at least three variables, explaining clearly how these affect the efficiency of the boat pulley.

Boat Pulley

Name(s): ______________________ **Date:** ______________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we identified those variables that affected our boat pulley's efficiency.				
Cause and effect: Mechanism and explanation. Use cause and effect relationships to explain observations in designed systems.	• We identified at least one variable that affect the efficiency of our boat pulley. ☐	• We met Bronze. • We identified two more variables that affect the efficiency of our boat pulley. ☐	• We met Silver. • For all three variables, we explained what effect they would have on the boat pulley's efficiency. ☐	• We met Gold. • We identified and explained the effect of at least one more variable on the boat pulley's efficiency. ☐
2. Student work related to this Practice: In this project, we built a boat pulley and investigated how much power was required to lift a load using two different pulley systems.				
Planning and carrying out investigations: Collect data to test design solutions under a range of conditions.	• We completed predictions and measurements for the average power our boat pulley needed to move the string with no load. ☐	• We met Bronze. • We completed predictions and measurements for our boat pulley while lifting a load. ☐	• We met Silver. • We rebuilt our boat pulley to include a moveable pulley. • We completed predictions and measurements for the new pulley system. ☐	• We met Gold. • We proposed a design for a new pulley system that contained two moving pulleys. • We predicted the average power our boat pulley would need with the new pulley system. ☐
3. Student work related to this Practice: In this project, we completed several mathematical calculations including Work and Efficiency.				
Using mathematics and computational thinking: Apply mathematical concepts such as ratio, percent, and basic operations to scientific and engineering questions.	• We obtained measurements for the force and distance required to lift the boat pulley's load. ☐	• We met Bronze. • We correctly calculated the Ideal Work needed to lift the load. • We used the Energy Meter to measure the Actual Work needed to lift the load. ☐	• We met Silver. • We calculated the boat pulley's efficiency. ☐	• We met Gold. • We completed the necessary measurements and calculations to determine the efficiency of the boat pulley with a moveable pulley in the system. ☐

Notes:

Lawn Mower

Solar energy can be captured and used in many ways. Solar panels convert solar energy into electrical energy, powering a variety of mechanisms.

The school's lawn needs to be mowed frequently during the spring and summer months.

Your task is to design and build a prototype solution of a lawn mower, powered by solar energy. Make sure it moves easily and is safe to use.

education

Self-Assessment

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.	• Our design met the goals or criteria defined by the activity. ☐	• We met Bronze • We tested our prototype multiple times. • We made at least one improvement. ☐	• We met Silver • We made at least two improvements. ☐	• We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. ☐
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	• We started the activity and have at least one possible solution that looks reasonable. ☐	• We brainstormed two to three ideas. • We built a working model to solve the problem. ☐	• We brainstormed more than three ideas. • We built an effective model to solve the problem. ☐	• 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. ☐
Collaboration: Work is shared effectively and the team encourages and helps each other.	• 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. ☐	• We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members. ☐	• We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose. ☐	• 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. ☐

Notes:

Lawn Mower

Objectives

Applying knowledge of:
- Applying principles of safety and product reliability
- Communicating and team working
- Designing a prototype solution or prototype product
- Engineering design
- Renewable energy sources

Other Materials Required (Optional)
- Materials for enhancing the appearance, design and functionality of the model

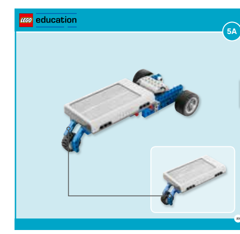
Motivation
- To help in the design process, instruct students to look at the picture on the student worksheet and read the accompanying text
- Let students search the Internet to learn more about the appearance, structure and function of different sorts of lawn mowers and solar powered vehicles
- Discuss the constraints and functions they will have to take into account as described by the task

When in progress, encourage students to relate their knowledge, skills and understanding to the task at hand by asking:
- How will your lawn mower work?
- What different sorts of elements will you need?
- How will you ensure that it is easy to use?
- What mechanism will cause it to move?
- How will you ensure that it is safe?
- How will you ensure that it is reliable?

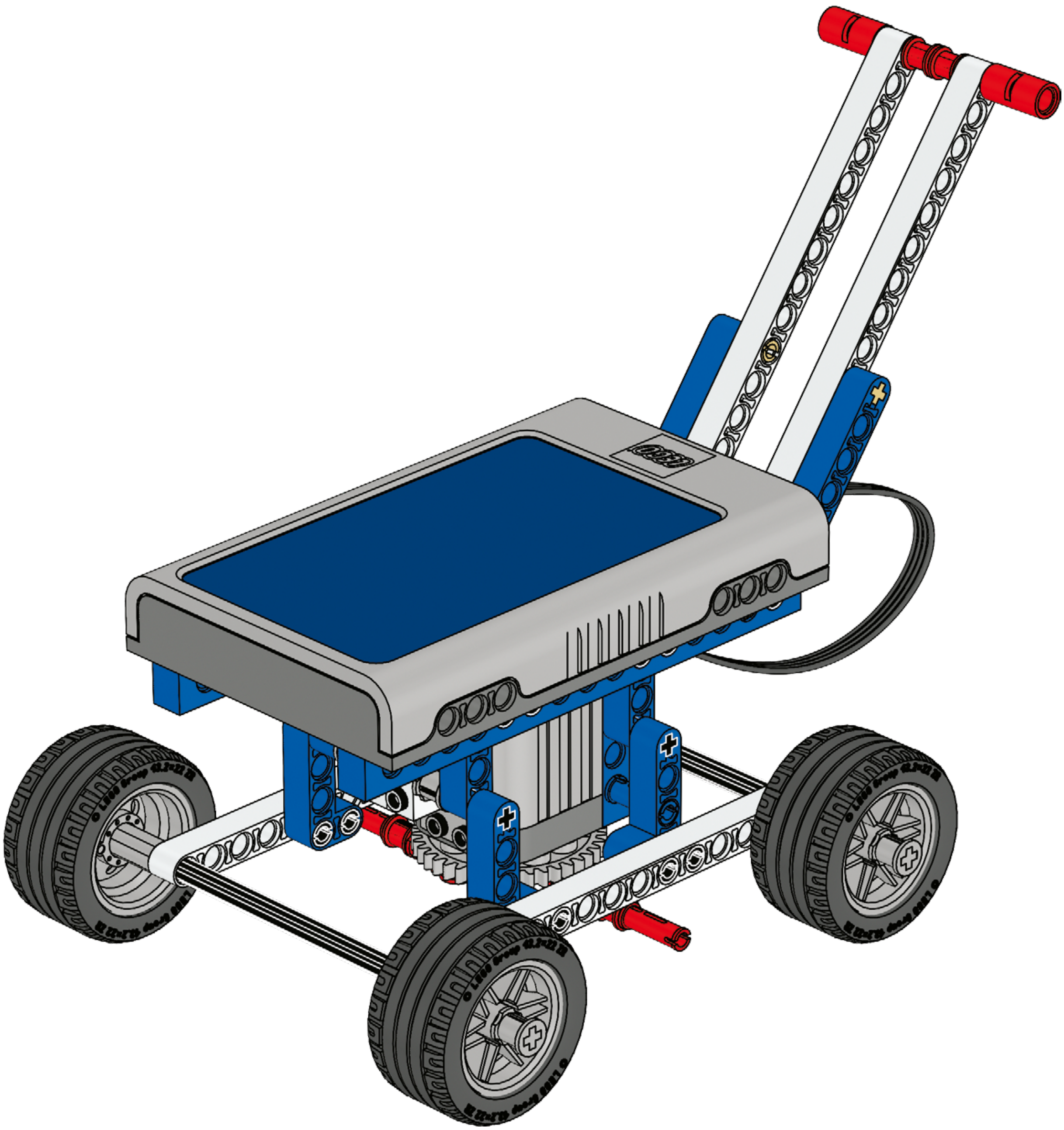
When finished constructing, encourage students to reflect on both the product that they have produced and the processes they have used by:
- Carrying out tests to evaluate the performance of the lawn mower:
  - Do the lawn mowers blades move efficiently? *To test if the lawn mower's blades move, as if cutting grass, try rolling small bits of paper together and see if the lawn mower can move them.*
  - How will your lawn mower work on a sunny day compared to a cloudy day?
  - How easy is it to use?
  - How safe is it?
  - How reliable is it?
  - What are its limitations, if any?
- Recording their design by drawing or taking digital photos
- Adding notes to describe the way the model works and how this might be improved to get better performance
- Writing briefly on what went well in their design task and what they could have done to improve it

Need help?
Look at:

Sweeper



Solar Vehicle



Suggested model, prototype solution

Observation Checklist Part 1

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.

		Name(s)										
Practice 1: I observed students asking questions												
a	to seek more information.											
b	to seek evidence for 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

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.

		Name(s)										
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 tradeoffs 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:

Moving Sign

Solar energy can be captured and used in many ways. Solar panels convert solar energy into electrical energy, powering a variety of mechanisms.

A local food vendor would like a moving sign on his cart. He is only open during the summer and he wants to be noticed by people walking by.

Your task is to design and build a prototype solution of a moving sign, powered by solar energy. Make sure it attracts attention.

education

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.	• Our design met the goals or criteria defined by the activity. ☐	• We met Bronze • We tested our prototype multiple times. • We made at least one improvement. ☐	• We met Silver • We made at least two improvements. ☐	• We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. ☐
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	• We started the activity and have at least one possible solution that looks reasonable. ☐	• We brainstormed two to three ideas. • We built a working model to solve the problem. ☐	• We brainstormed more than three ideas. • We built an effective model to solve the problem. ☐	• 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. ☐
Collaboration: Work is shared effectively and the team encourages and helps each other.	• 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. ☐	• We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members. ☐	• We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose. ☐	• 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. ☐

Notes:

Moving Sign

Objectives

Applying knowledge of:

- Applying principles of product reliability
- Communicating and team working
- Designing a prototype solution or prototype product
- Engineering design
- Renewable energy sources

Other Materials Required (Optional)

- Materials for enhancing the appearance, design and functionality of the model

Motivation

- To help in the design process, instruct students to look at the picture on the student worksheet and read the accompanying text
- Let students search the Internet to learn more about the appearance, structure and function of different sorts of sorts of carts and signs
- Discuss the constraints and functions they will have to take into account as described by the task

When in progress, encourage students to relate their knowledge, skills and understanding to the task at hand by asking:

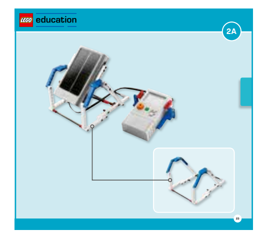
- How will your moving sign work?
- What different sorts of elements will you need?
- How will you ensure that it is easy to use?
- What mechanism will cause it to move?
- How will you ensure that it is reliable?
- How does the sign reflect what is being sold?
- How will you ensure that it attracts attention?

When finished constructing, encourage students to reflect on both the product that they have produced and the processes they have used by:

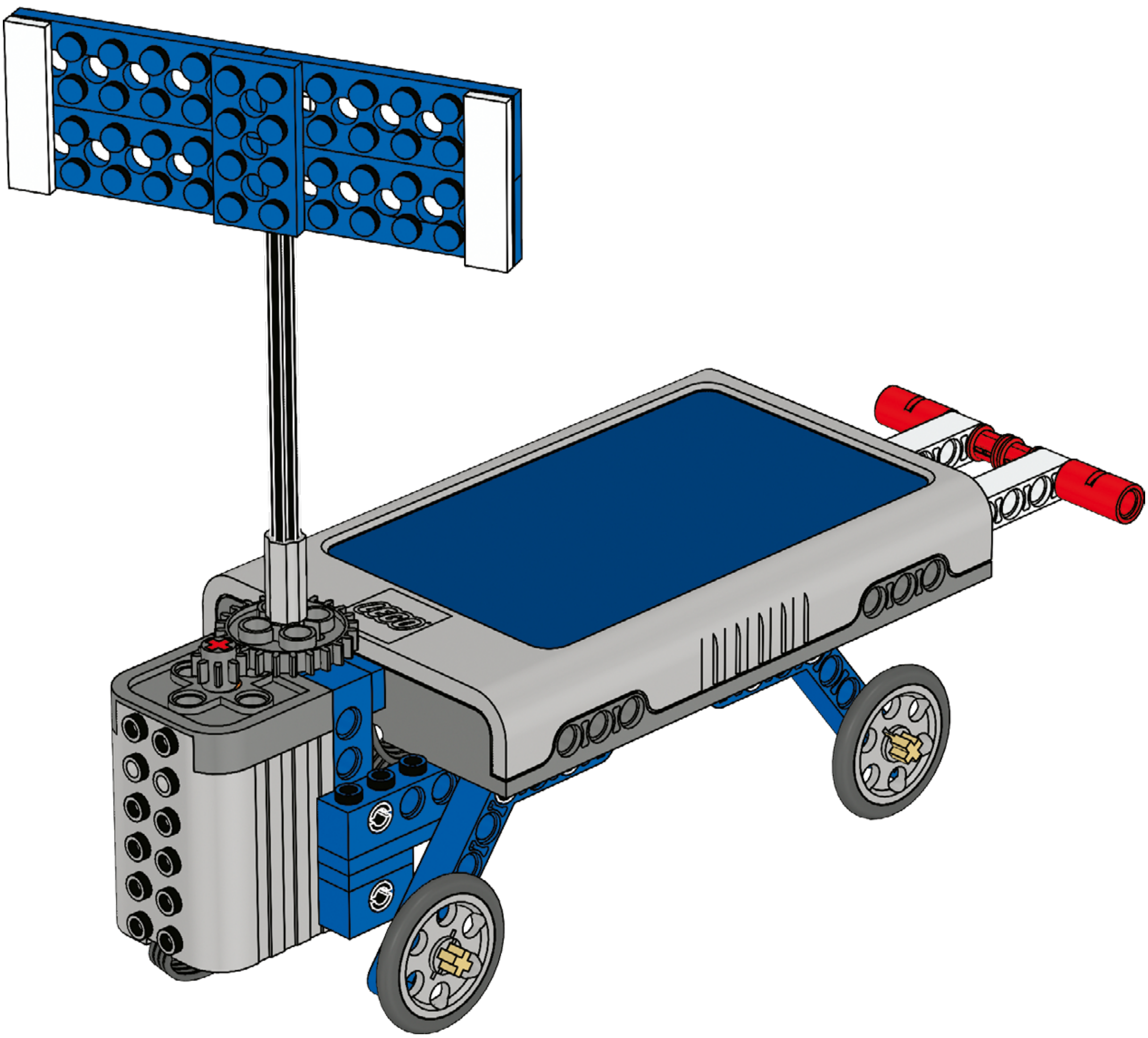
- Carrying out tests to evaluate the performance of the moving sign:
  - Does the moving sign attract attention? *To test if the moving sign attracts the attention of other students, let your students take it outside class and observe what happens*
  - How will your moving sign work on a sunny day compared to a cloudy day?
  - How easy is it to use?
  - How reliable is it?
  - What are its limitations, if any?
- Recording their design by drawing or taking digital photos
- Adding notes to describe the way the model works and how this might be improved to get better performance
- Writing briefly on what went well in their design task and what they could have done to improve it

Need help?
Look at:

Dogbot



Solar Station



Suggested model, prototype solution

Observation Checklist Part 1

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.

		Name(s)										
Practice 1: I observed students asking questions												
a	to seek more information.											
b	to seek evidence for 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

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.

		Name(s)										
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 tradeoffs 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:

Motorized Fan

Renewable energy sources can be captured and used in many ways. A variety of mechanisms can be powered by a renewable energy source.

The school auditorium is where students and teachers gather together at the beginning and end of each school year. With so many people in one place it can get very warm; they need a fan to circulate the air.

Your task is to design and build a prototype solution of a motorized fan, powered by a renewable energy source. Make sure it makes the air circulate and is safe to use.

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.	• Our design met the goals or criteria defined by the activity. ☐	• We met Bronze • We tested our prototype multiple times. • We made at least one improvement. ☐	• We met Silver • We made at least two improvements. ☐	• We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. ☐
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	• We started the activity and have at least one possible solution that looks reasonable. ☐	• We brainstormed two to three ideas. • We built a working model to solve the problem. ☐	• We brainstormed more than three ideas. • We built an effective model to solve the problem. ☐	• 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. ☐
Collaboration: Work is shared effectively and the team encourages and helps each other.	• 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. ☐	• We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members. ☐	• We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose. ☐	• 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. ☐

Notes:

Motorized Fan

Objectives

Applying knowledge of:
- Applying principles of product reliability
- Communicating and team working
- Designing a prototype solution or prototype product
- Engineering design
- Renewable energy sources

Other Materials Required (Optional)

- Materials for enhancing the appearance, design and functionality of the model

Motivation

- To help in the design process, instruct students to look at the picture on the student worksheet and read the accompanying text
- Let students search the Internet to learn more about the appearance, structure and function of different sorts of fans and rotating mechanisms
- Discuss the constraints and functions they will have to take into account as described by the task

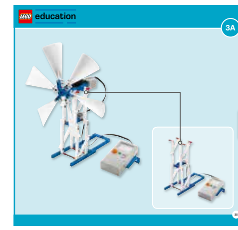
When in progress, encourage students to relate their knowledge, skills and understanding to the task at hand by asking:

- Which renewable energy source would be most appropriate to use?
- How will your motorized fan work?
- What different sorts of elements will you need?
- How will you ensure that it is easy to use?
- What mechanism will cause it to move?
- How will you ensure that it is safe?
- How will you ensure that it is reliable?

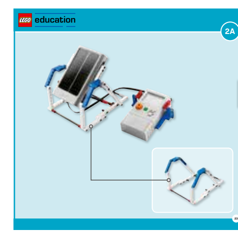
When finished constructing, encourage students to reflect on both the product that they have produced and the processes they have used by:

- Carrying out tests to evaluate the performance of the motorized fan:
  - Which renewable energy source did you find most appropriate to use and why?
  - How easy is it to use?
  - How safe is it?
  - How reliable is it? *To test if the motorized fan can circulate air, try rolling small bits of paper together and see if the motorized fan can move them*
  - What are its limitations, if any?
- Recording their design by drawing or taking digital photos
- Adding notes to describe the way the model works and how this might be improved to get better performance
- Writing briefly on what went well in their design task and what they could have done to improve it

Need help?
Look at:



Wind Turbine



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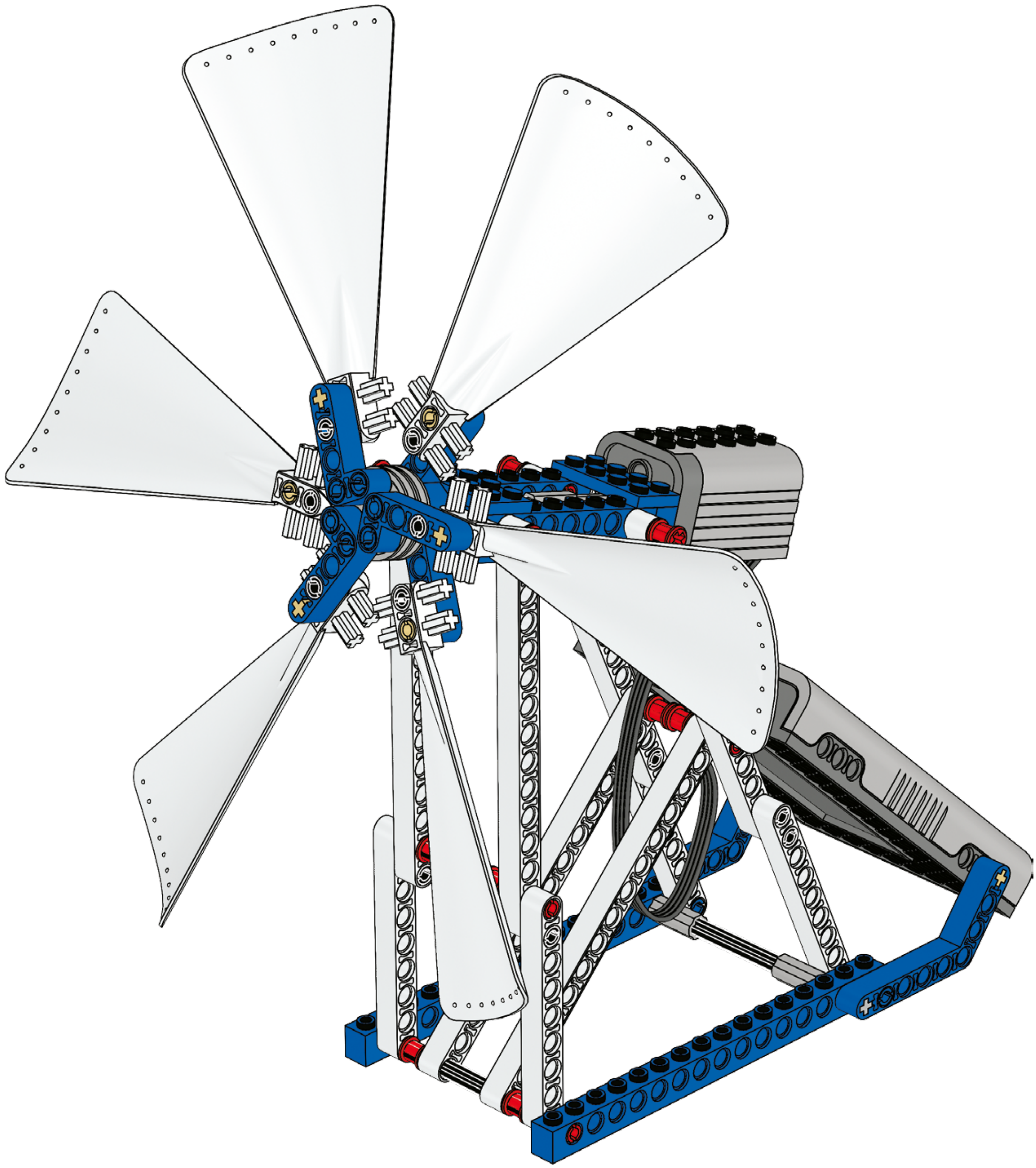

Suggested model, prototype solution

Observation Checklist Part 1

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.

		Name(s)										
Practice 1: I observed students asking questions												
a	to seek more information.											
b	to seek evidence for 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

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.

		Name(s)										
	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 tradeoffs 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:

Court Lights

Renewable energy sources can be captured and used in many ways. A variety of mechanisms can be powered by a renewable energy source.

The school's basketball team needs a lighting system to enable them to train after dark.

Your task is to design and build a prototype solution for a lighting system, powered by a renewable energy source. Make sure it can be used after dark.

LEGO education

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.	• Our design met the goals or criteria defined by the activity. ☐	• We met Bronze • We tested our prototype multiple times. • We made at least one improvement. ☐	• We met Silver • We made at least two improvements. ☐	• We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. ☐
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Notes:

Court Lights

Objectives

Applying knowledge of:

- Applying principles of product reliability
- Communicating and team working
- Designing a prototype solution or prototype product
- Engineering design
- Renewable energy sources

Other Materials Required (Optional)

- Materials for enhancing the appearance, design and functionality of the model

Motivation

- To help in the design process, instruct students to look at the picture on the Student Worksheet and read the accompanying text
- Let students search the Internet to learn more about the appearance, structure and function of different sorts of lightning systems and renewable energy light applications
- Discuss the constraints and functions they will have to take into account as described by the task

When in progress, encourage students to relate their knowledge, skills and understanding to the task at hand by asking:

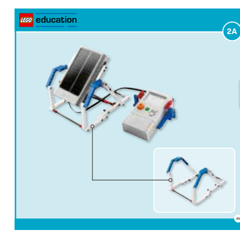
- Which renewable energy source would be most appropriate to use?
- How will your court lights work?
- What different sorts of elements will you need?
- How will you ensure that it is easy to use?
- How will you ensure that it is reliable?

When finished constructing, encourage students to reflect on both the product that they have produced and the processes they have used by:

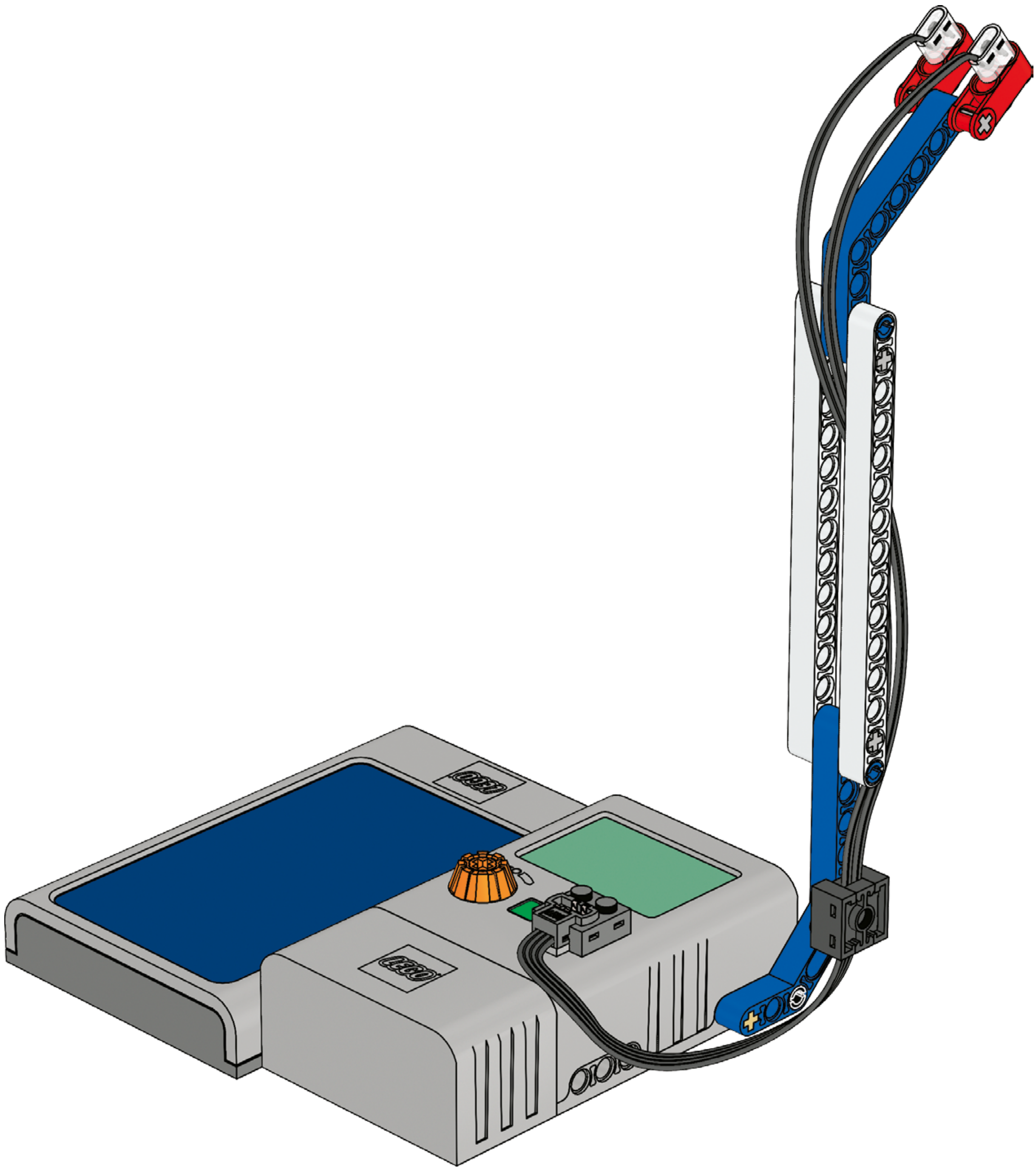
- Carrying out tests to evaluate the performance of the court lights:
  - Which renewable energy source did you find most appropriate to use and why?
  - How easy is it to use?
  - How reliable is it? *To test if the court lights can light after dark, place them in a dark room and time how long they can stay on*
  - What are its limitations, if any?
- Recording their design by drawing or taking digital photos
- Adding notes to describe the way the model works and how this might be improved to get better performance
- Writing briefly on what went well in their design task and what they could have done to improve it

Need help?
Look at:

Hand Generator



Solar Station



Suggested model, prototype solution

Observation Checklist Part 1

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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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 **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.		Name(s)										
Practice 5: I observed students using mathematics and computational thinking												
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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:

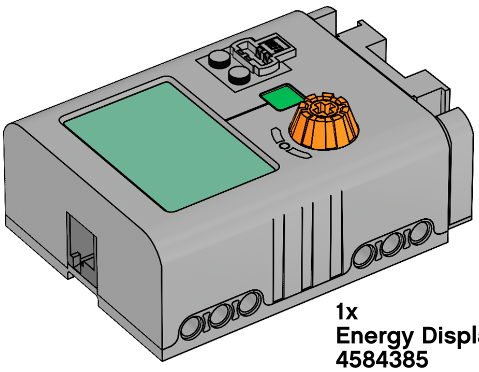
Glossary

A	**Ampere (A)**	The SI unit of electrical current. Ampere is the amount of electric charges per second.
B	**Barrage**	A water channel that is controlled at its head by a gate or a sluice. A barrage is typically an artificial obstruction, designed to either increase a river's depth or to divert its flow. See Head.
C	**Current (A)**	A flow of electrons through a conductor. Current is measured in ampere (A), often called amps.
D	**Distance**	A physical length describing how far objects are apart, referred to by a numerical description.
E	**Efficiency**	Defined as energy out divided by energy in, or the ratio between input and output, usually converted to a percentage. The efficiency of a machine can be described as the ratio between how much work goes into a machine and how much comes out as useful work. Friction often wastes a lot of energy, reducing the efficiency of a machine.
	Elastic Potential Energy	A potential energy due to the deformation of a material. See Potential Energy.
	Energy (J)	The capacity to do work. The SI unit of energy is the joule (J).
	Energy Conversion	The process of transforming energy from one form to another.
F	**Flow Rate**	The rate by which water is discharged from an opening, usually measured in litres per hour.
	Friction	The resistance met when one surface is sliding over another, e.g. when an axle is turning in a hole or when you rub your hands together.
G	**Generator**	This is a device containing magnets and coils of wire which, when they rotate relative to each other, convert kinetic energy into electrical energy.
	Gravitational Acceleration	The acceleration of an object due to gravity. Normally considered to be 9.8 m/s^2, but will vary depending on elevation.
	Gravitational Potential Energy	The potential energy of an object as the result of its vertical height, mass and the gravitational attraction of the Earth. See Potential Energy.
H	**Head**	The distance or drop in height from where the water flow starts at the outlet or opening, until it reaches a generator turbine.

J	**Joule (J)**	The SI unit of measurement of energy work and heat is the joule (J). One joule is the amount of work done by a force of 1 N acting through a distance of 1 m in the same direction of the force. One Joule is one watt applied for the time of one second (1 Ws).
K	**Kinetic Energy**	The energy of an object that is related to its motion. The faster it travels, the more kinetic energy it has.
M	**Mass (kg)**	The SI unit for mass is kilogram (kg). Mass is the amount of matter in an object. See Weight (N).
	Mechanical Energy	Describing the potential or kinetic energy that can be used directly to do work in the components of a mechanical system.
N	**Non-renewable Energy**	Energy derived from a finite source, like coal, oil and gas.
P	**Perpendicular to**	When two planes are perpendicular to each other, in the case of the Solar Station, the lamp bulb and the solar panel, they are positioned with an angle of 90 degrees between them. One straight line at right angles to another straight line is perpendicular to that straight line.
	Photovoltaic	Derived from the words photo (meaning light) and volt (electricity), referring to technological systems that produce voltage when exposed to radiant energy (in particular sunlight).
	Potential Energy	The energy of an object that is related to its position. It is a form of stored energy. An object held above the floor has potential energy. A stretched elastic band or spring has potential energy.
	Power (W)	The rate of transfer of energy. The rate of doing work is called power. The electrical unit of power is called the watt (W).
R	**Renewable Energy**	Energy derived from naturally occurring and inexhaustible sources, like wind, sun and moving water.
S	**SI**	The International System of Units.
	Solar Cell	Individual photovoltaic cells are wired together in series and parallel to make modules convert light energy directly into electrical energy. See Solar Panel.
	Solar Panel	A group of solar cells arranged into a panel, providing an increased output. See Solar Cell.
	Solar Radiation	Radiant electromagnetic energy emitted by the sun, including ultraviolet and infrared wave lengths as well as visible light.
	Speed	The rate at which an object moves. Speed can be calculated using this formula: $\text{Speed} = \frac{\text{Distance traveled}}{\text{Time taken}}$

T	**Torque**	The applied force creating a rotational motion, also called a moment of force.
	Turbine	A rotary machine that converts kinetic energy into electrical energy. It can be operated by steam, water or wind.
V	**Variable**	A quantity that can take on different values or is likely to vary.
	Volt (V)	The SI unit of electromotive force or electrical potential difference, measured in volts (V).
	Voltage	The force driving the flow of electrical energy. Voltage is measured in volts (V).
W	**Watt (W)**	The SI unit for the rate at which work is done is the watt (W). The watt is the unit of measurement for power. One watt is the equal to one joule (J) per second.
	Wattage	The amount of work done in a given time, a measure of power. See Watt (W).
	Water Pressure	The force or pressure of a column of water, where the pressure exerted by the confined water is forced downward caused by the pull of the Earth's gravity in any water supply system.
	Weight (N)	Weight is a measure of the force that gravity exerts on an object. Since weight is affected by gravity, an object would weigh less on the moon, where the gravitational field strength is less. Weight is a force and measured in Newtons (N).
	Work	The application of a force over a distance. Work done can be calculated by multiplying the force needed to move an object by the distance it is moved (Force x Distance).

LEGO® Element Survey



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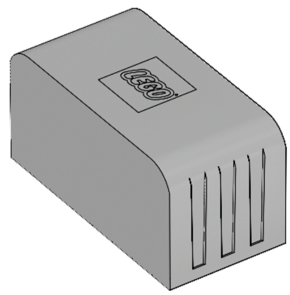

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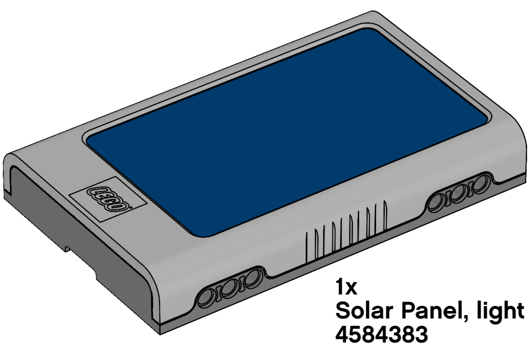

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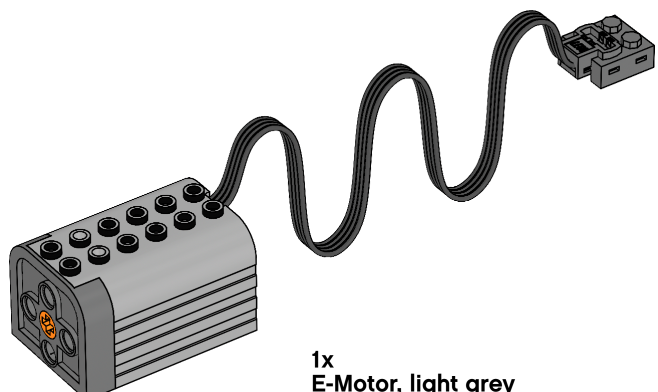

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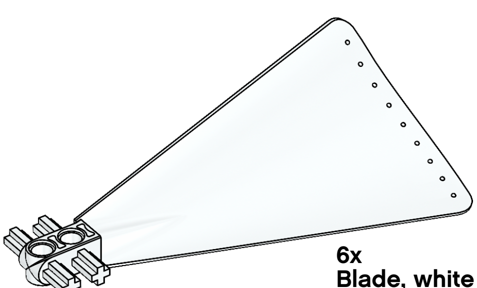

6x
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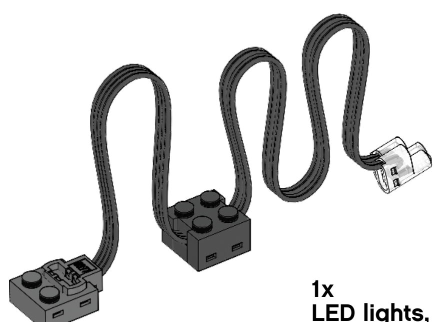

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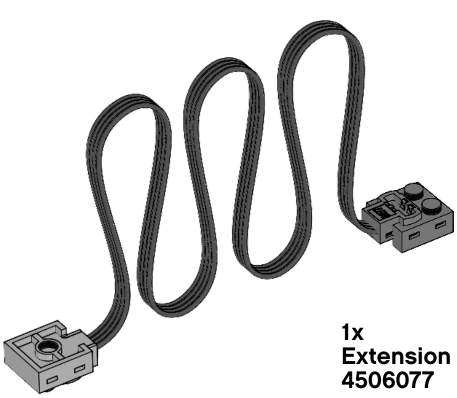

1x
Extension Wire, 50 cm (= 19 in.)
4506077

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