

2009688



education



Hydro Wind Solar Investigate Technology Power Renewable Energy



Teacher's Guide



Table of Contents

1. Introduction	3
2. Curriculum	8
3. Teacher's Resources	
3.1 Renewable Energy.....	12
3.2 Potential and Kinetic Energy.....	17
3.3 Element Guide.....	23
4. Activities	
4.1 Hand Generator.....	31
4.2 Solar Station	38
4.3 Wind Turbine	45
4.4 Hydro Turbine.....	53
4.5 Solar Vehicle.....	60
4.6 Boat Pulley.....	67
5. Problem-solving Activities	
5.1 Lawn Mower	75
5.2 Moving Sign.....	78
5.3 Motorised Fan.....	81
5.4 Court Lights.....	84
6. Glossary	87
7. LEGO® Element Survey.....	90



Introduction

LEGO® Education is pleased to bring you the 2009688 Activity Pack for Renewable Energy Add-on Set.

Who is it for?

The material is designed for introducing and teaching the topic of renewable energy for key stage 2 and key stage 3. Working in teams, students can build, investigate and learn from the models and activities.

What is it for?

The Renewable Energy activity pack and Add-on Set enables students to work as young scientists, engaging them in science, engineering, technology, design and mathematics. The Renewable Energy activity 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 the activity pack, students are encouraged to involve themselves in real world investigations and to come up with their own solutions for solving specific problems. They are asked to design and redesign, to build and reflect on the models. They are also asked to observe and explain how changing variables affect these models and then to record and present their findings. In this way, the students experience for themselves how engineers and designers use scientific knowledge and understanding.

What is in the set and the activity pack?

The 9688 elements

The set consists of five full-colour Building Instruction 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 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.

The 2009688 activity pack

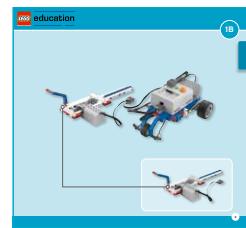
The activity pack consists of six main model activities and four Problem-solving Activities that deal with potential and kinetic energy. Also included is a curriculum section that pinpoints the key learning concepts covered, Teacher's Resources with a short introduction to the topic Renewable Energy and a section regarding potential and kinetic energy, an element guide and a glossary with definitions of essential terms.



How to use it?

Building Instructions

There are two Building Instructions, booklet A and B, for each of the main models. 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 Resources

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 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 Renewable Energy, including a section on class discussion.

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Renewable Energy

Renewable Energy

Solar energy is the energy received from the Sun. The Sun generates the energy that drives our weather systems and our water cycle. The Sun is the primary energy source for all forms of life on Earth. Renewable energy is the exploitation of energy from renewable sources such as the Sun, wind, water, and the earth. It is a sustainable form of energy that does not deplete over time.

Sun

The Sun is a spherical star at the center of the solar system. It is the largest object in the solar system and is responsible for most of the energy available on Earth. The Sun is a nuclear fusion reactor that converts hydrogen into helium, which releases energy and light.

Wind

The Sun's heat causes the air to move, creating wind. Wind is a form of kinetic energy that can be harnessed to move objects or generate electricity.

Water

The Sun's heat causes the water in rivers, lakes, and oceans to move, creating waves and currents. This movement can be harnessed to generate electricity.

Geothermal

The Sun's heat causes the rocks in the ground to move, creating geothermal energy. This energy can be harnessed to generate electricity.

Class Discussion

Discuss the following questions with your class. Ask them to think about what they know about renewable energy and how it can be used to power our world.

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Solar Energy

Solar Energy

Solar energy can be harvested by big, solar cells. Solar cells convert sunlight into electrical energy. This energy can be used to power small electronic devices like calculators or mobile phones. It can also be used to power larger systems like homes or businesses.

Passive solar energy

In which the energy is harnessed to heat a building or a room. This is done by using materials that absorb the sun's heat and release it slowly over time.

Active solar water heating systems

Active solar water heating systems use the sun's energy to heat water. This is done by using a collector panel to collect the sun's heat and transfer it to a tank where the water is heated.

Photovoltaic cells

Photovoltaic cells convert sunlight directly into an electric current or direct current (DC). This is done by using the photovoltaic effect, which converts light energy into electrical energy.

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 Worksheet and Building Instruction booklets, students will be challenged further to apply their knowledge while investigating and recording their findings. In Teacher's Notes, you will find suggested answers to the questions posed in the Student Worksheet.

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Potential and Kinetic Energy

Potential and Kinetic Energy

Energy cannot be created or destroyed as stated in the Law of Conservation of Energy. A car moving down a hill has potential energy because it can do work as it moves down the hill. Potential energy is the energy stored in an object due to its position or state. Kinetic energy is the energy of motion. Potential energy is converted into kinetic energy when an object moves from a higher position to a lower position.

Investigation

In other words, this activity is a model case for how the surface plane has potential energy because it is higher than the ground. When the ball is moved to a higher position, it has potential energy. When the ball is moved to a lower position, it has kinetic energy.

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Chemical and Nuclear Energy

A1

Building Instructions booklet - page 8 (page 10)

A2

Building Instructions booklet - page 9 (page 11)

A3

Building Instructions booklet - page 10 (page 12)

Element Guide

This section describes how to get started with the 9688 Renewable Energy Add-on Set. 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.

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LEGO® Energy Meter

LEGO® Energy Meter

The LEGO® Energy Meter is a device that measures the amount of energy stored in a battery. It can be used to measure the energy stored in a battery or a motor. To use the Energy Meter, simply turn it on and place it next to the battery or motor you want to measure. The meter will then display the amount of energy stored in the battery or motor.

To charge the Energy Meter

To charge the Energy Meter, simply turn it on and place it next to a battery or motor. The meter will then display the amount of energy stored in the battery or motor.

To discharge the Energy Meter

To discharge the Energy Meter, simply turn it off and place it next to a battery or motor. The meter will then display the amount of energy stored in the battery or motor.

Energy Meter

How to charge and discharge the Energy Meter

How to charge and discharge the Energy Meter

The Energy Meter can be charged and discharged using a USB cable. To charge the Energy Meter, simply turn it on and place it next to a battery or motor. The meter will then display the amount of energy stored in the battery or motor.

To charge the Energy Meter

To charge the Energy Meter, simply turn it on and place it next to a battery or motor. The meter will then display the amount of energy stored in the battery or motor.

To discharge the Energy Meter

To discharge the Energy Meter, simply turn it off and place it next to a battery or motor. The meter will then display the amount of energy stored in the battery or motor.

Teacher's Notes

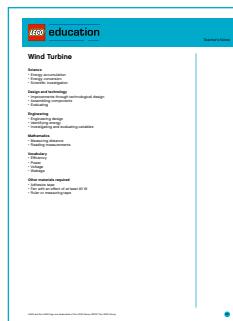
This section describes key learning areas, hints, questions, answers and vocabulary specific to the activity, and further ideas for investigation. In some cases, additional materials will be necessary for setting up the activities and investigations. These will be listed.

The lessons follow LEGO® Education's 4C approach: Connect, Construct, Contemplate and Continue. This approach enables your students 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**

Constructing models engages both hands and minds. Using the Building Instructions, students build models embodying the concepts related to the key learning areas. Suggestions 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.

Wind Turbine

Lesson 1

Setup and Materials

Build the Wind Turbine

Blade blades and changing the distance

Blade position	30 cm	45 cm
DC motor torque	0.1	0.2
DC motor voltage	0.1	0.2

Measuring variables

Identify and write down three other variables, explaining clearly how these affect the efficiency of the Wind Turbine.

Wind Turbine

Lesson 2

Setup and Materials

Three blades and changing the distance

Wind Turbine

Measuring variables

Student Worksheets

Each worksheet has a focused approach following the 4Cs and includes easy-to-read pictorial guidelines. The students can use and explore their models with little teacher assistance. They will be able to predict, investigate, measure, read and record findings, change the models to compare and contrast findings, and draw conclusions.

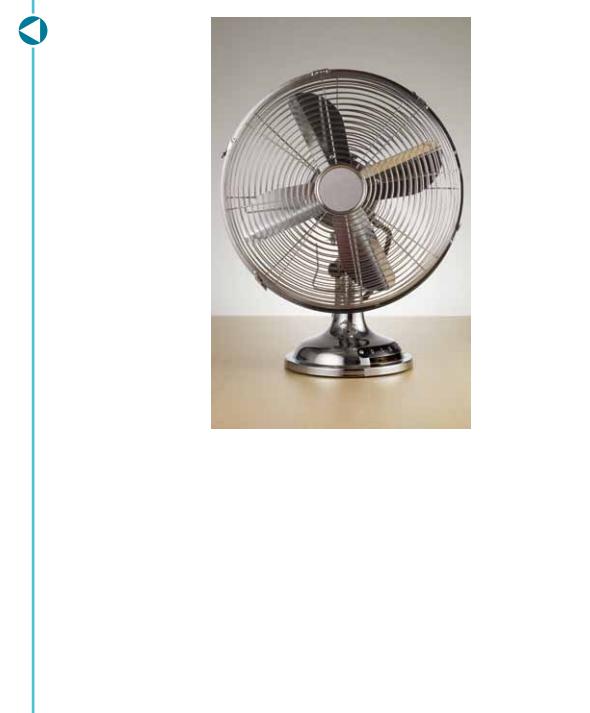
We suggest that students are allowed to work in teams. Each activity challenges students to predict an outcome, to investigate and finally read and record findings. Students should be encouraged to investigate their predictions at least three times to be confident that their results are reliable. When 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.

The worksheets are an easy-to-use tool for assessing the individual student's level and achievement. They can also form a valuable part of the student's log books.

Problem-solving Activities

The four Problem-solving Activities focus on applying knowledge of different renewable energy sources, engineering design, communication and team work. They all feature real-life settings describing a problem that needs to be solved. Students are then challenged to solve the problem through their own design.

The problem descriptions and the clearly defined design brief are meant to be copied and used by the students. A description of learning objectives, materials needed, and how to progress and evaluate the task at hand is teacher information only!



The suggested Problem-solving model solutions included are only meant as guiding principles to the problems posed. Students should always be encouraged to design their own solutions. The Problem-solving Activities are open to be differentiated to fit your current curriculum.

How do I handle the Building Instruction booklets?

For easy classroom management we suggest storing the Building Instruction booklets in binders so that they are close-at-hand and ready to use at the beginning of each lesson.

How much time is needed?

A double lesson is 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 main models can be built, investigated and explored, and the parts put away again within a single lesson if the students are already experienced LEGO® builders.

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

Enjoy!
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Curriculum

The process of students actively building, exploring, investigating, enquiring 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 enquiry, predicting and measuring, collating data and drawing conclusions.

Design and 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.

Mathematics

Using mathematics in the service 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.

	Hand Generator	Solar Station
Science curriculum:	<ul style="list-style-type: none"> Consider evidence from observations, and experiment using 'distance travelled' as a measure of performance Transfer, transformation, storage and dissipation of energy with reference to conversion of kinetic energy to electrical energy 	<ul style="list-style-type: none"> Consider evidence from observations, and experiment using 'average voltage and current' as a measure of performance Transfer, transformation, storage and dissipation of energy with reference to conversion of solar energy to electrical energy
Design and technology curriculum:	<ul style="list-style-type: none"> Construct with components Investigate and predict effect of gearing systems on generator performance 	<ul style="list-style-type: none"> Construct with components Investigate and predict the effect of angles of illumination on Solar Panel performance
Mathematics curriculum:	<ul style="list-style-type: none"> Present investigation and prediction data graphically Applications of ratio and proportion 	<ul style="list-style-type: none"> Present investigation and prediction data in tabular form Using bearings

	Wind Turbine	Hydro Turbine
Science curriculum:	<ul style="list-style-type: none"> Consider evidence from observations, and experiment using 'average voltage and power' as a measure of performance Transfer, transformation, storage and dissipation of energy with reference to conversion of wind energy to electrical energy 	<ul style="list-style-type: none"> Consider evidence from observations, and experiment using 'joules accumulated' as a measure of performance Transfer, transformation, storage and dissipation of energy with reference to conversion of hydro energy to electrical energy
Design and technology curriculum:	<ul style="list-style-type: none"> Construct with components Investigate and predict the effect of number of blades and distance from wind source on Wind Turbine performance 	<ul style="list-style-type: none"> Construct with components Investigate and predict the effect of number of blades on Hydro Turbine performance
Mathematics curriculum:	<ul style="list-style-type: none"> Present investigation and prediction data in tabular form 	<ul style="list-style-type: none"> Present investigation and prediction data graphically

	Solar Vehicle	Boat Pulley	Potential / Kinetic Energy Models
Science curriculum:	<ul style="list-style-type: none"> Consider evidence from observations, and experiment using 'speed of movement' as a measure of performance Transfer, transformation, storage and dissipation of energy with reference to conversion of solar energy to electrical energy 	<ul style="list-style-type: none"> Consider evidence from observations, and experiment using 'joules expended' as a measure of performance Transfer, transformation, storage and dissipation of energy with reference to conversion of electrical energy to potential energy 	<ul style="list-style-type: none"> Consider evidence from observations, and experiment to develop explanations concerned with the conversion of potential energy to kinetic energy
Design and technology curriculum:	<ul style="list-style-type: none"> Construct with components Investigate and predict the effect of gearing systems on the performance of a Solar Vehicle 	<ul style="list-style-type: none"> Construct with components Investigate and predict the effect of pulley systems on the performance of a Boat Pulley hoist 	<ul style="list-style-type: none"> Construct with components
Mathematics curriculum:	<ul style="list-style-type: none"> Present investigation and prediction data in tabular form Calculate speed 	<ul style="list-style-type: none"> Present investigation and prediction data in tabular form Calculate work done and efficiency 	



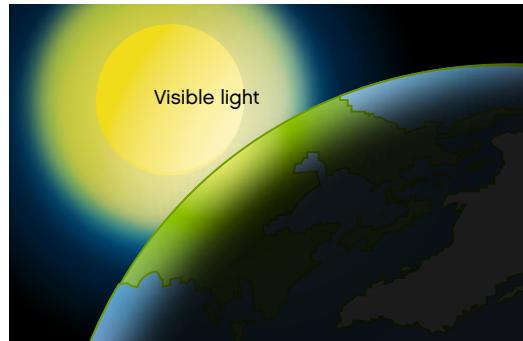
Renewable Energy

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.

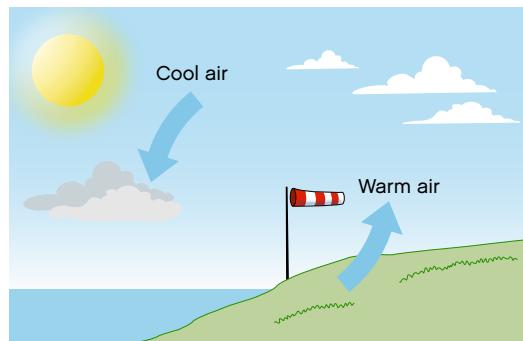
Sun

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, e.g., 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.



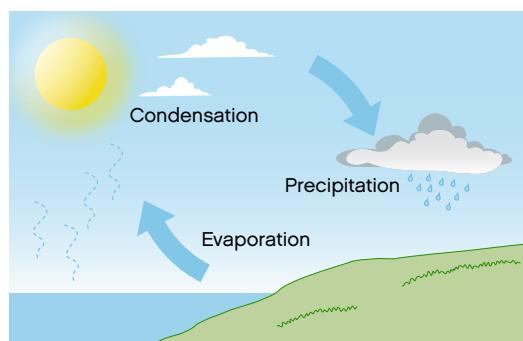
Wind

The Sun's heat is absorbed quicker by land than by the ocean. Warm air over land is less dense than 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 is 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 vapour into the air. This water vapour condenses into clouds and falls back to the surface as precipitation, e.g., rain and snow. The water flows through streams and rivers back into the oceans, where it can evaporate and begin the cycle over again.

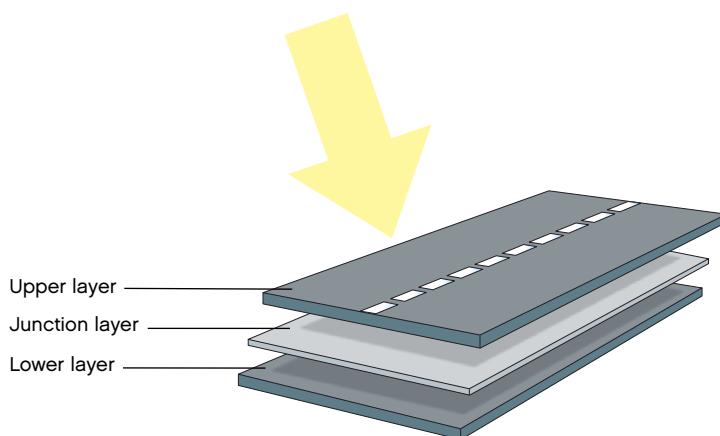


Solar Energy



Solar energy can be captured by, e.g., solar cells. Many solar cells assembled together are called solar panels. Solar panels are designed to capture the sun's 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 optimised.
- **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.



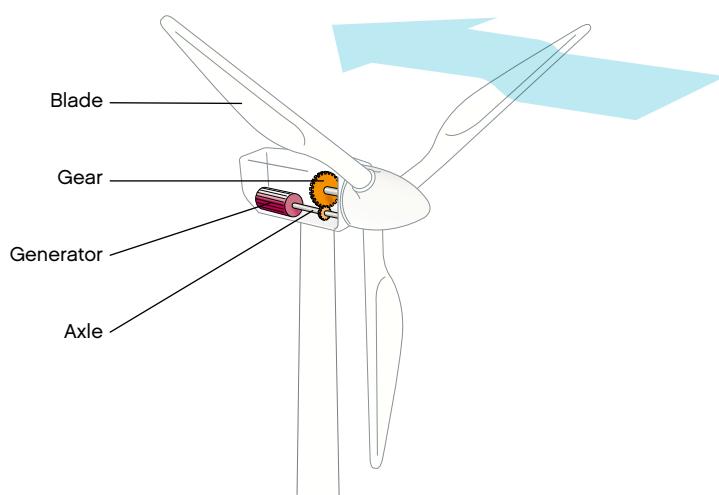
Wind Energy



Wind energy can be captured by, e.g., 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 effective 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.

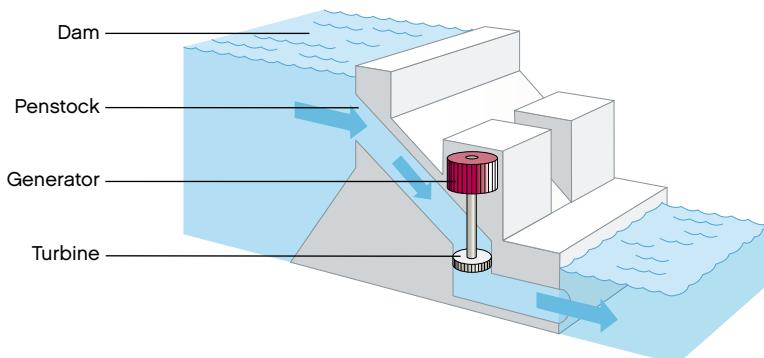


Hydro Energy



Hydro energy can be captured by, e.g., 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 funnelled 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 in the gates are closed, creating a large 'head' of water. When the tide flows back, the receding water is channelled 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 categorised as either potential energy or kinetic energy.

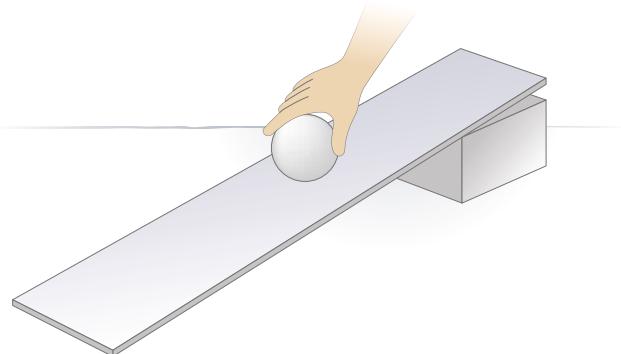
Potential Energy

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.

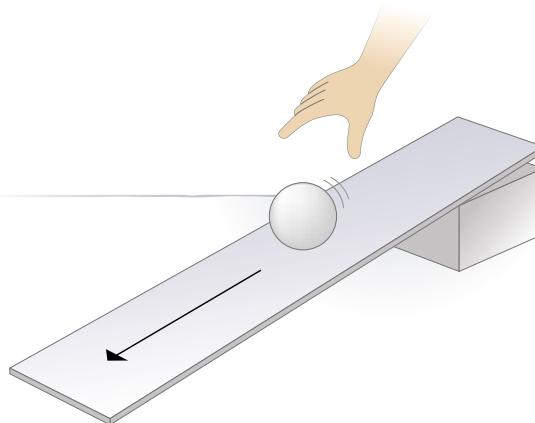


In other words, this means the more you stretch it the more elastic potential energy it will contain. If you let go of the elastic band its potential energy will be released and converted to kinetic energy as the elastic band contracts and returns to its original shape.

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.

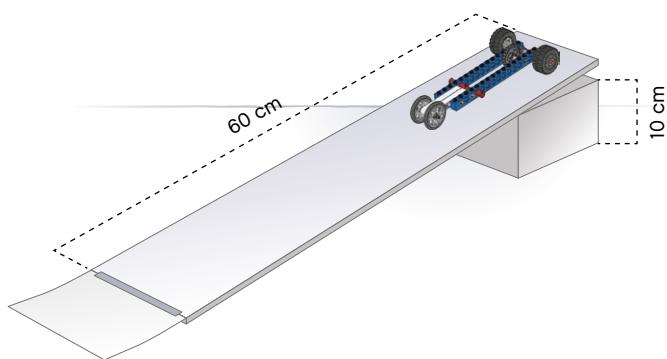
The ball that is being held half way up the inclined plane has potential energy but no kinetic energy, as it is not moving. If the ball is released and it started to roll down the inclined plane it would be gaining kinetic energy. How much it gains will depend on its mass and velocity.



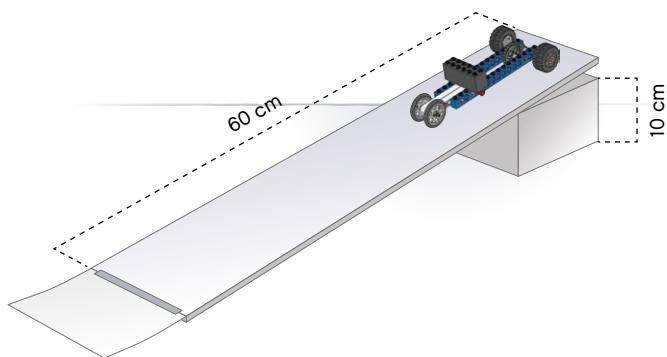
In other words, this means that a heavier ball rolling down the inclined plane will have more kinetic energy than a lighter ball rolling from the same position. A ball rolling from the top of the inclined plane will be travelling faster by the time it reaches the bottom of the inclined plane than a ball 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

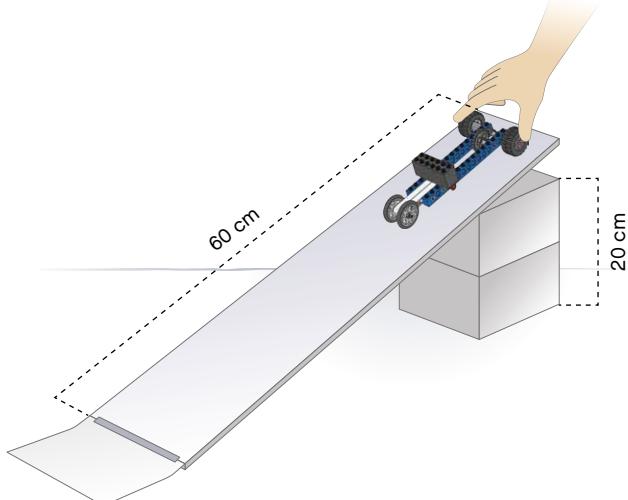
Potential energy is transformed to kinetic energy as the cart rolls down the ramp. The cart has greatest potential energy at its starting point and greatest kinetic energy at the bottom of the ramp.

**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.

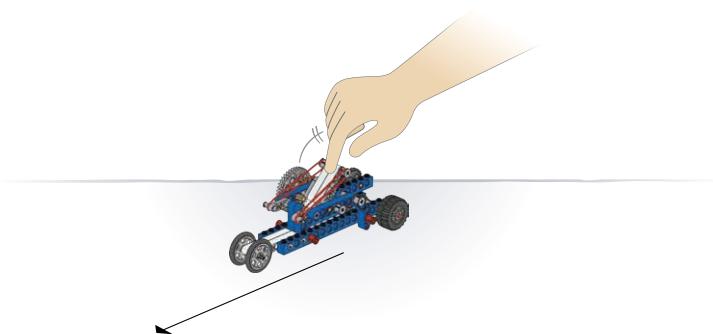
**A3**

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.



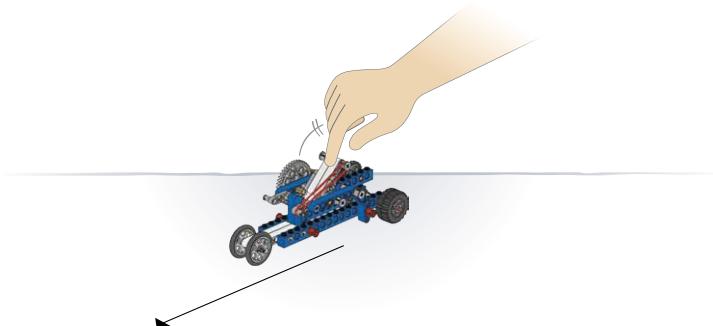
A4

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**

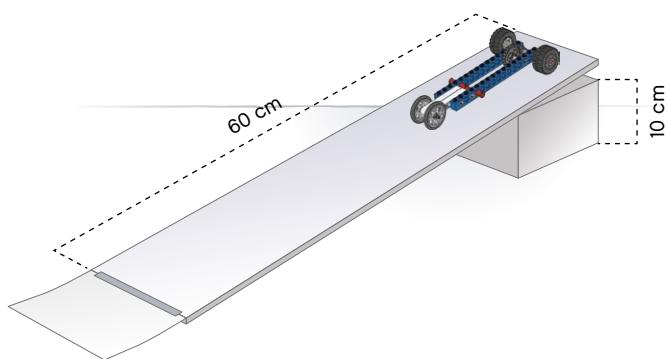
Due to the removal of an elastic band, there is a decrease in potential energy, which makes the cart move a shorter distance.

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.

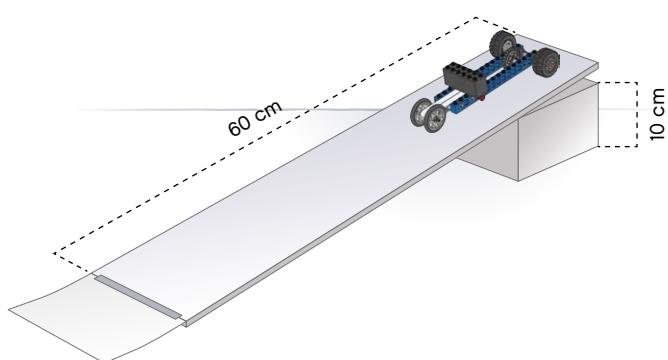


A1

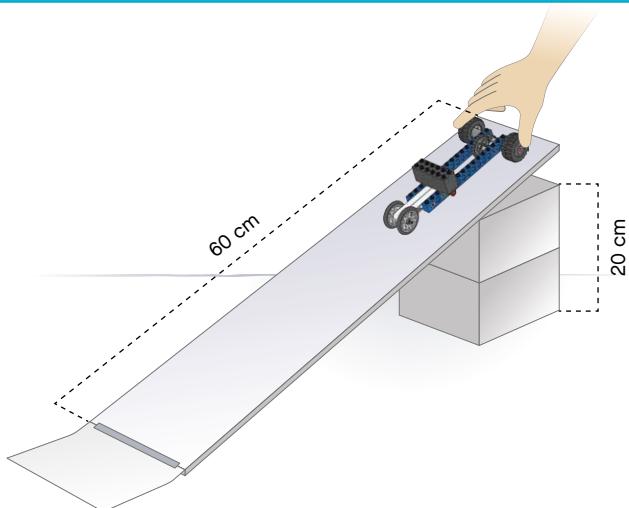
(Building Instruction booklet I, page 9 step 11).
Let the cart roll down the ramp and explain what has happened in terms of potential and kinetic energy.

**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.

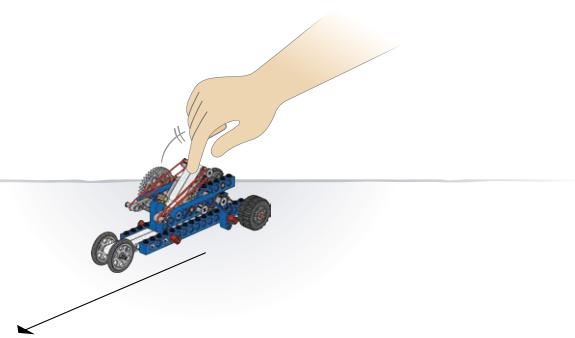
**A3**

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

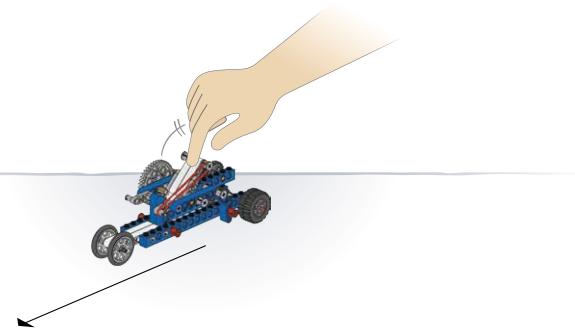


A4

(Building Instruction booklet I, page 18 step 27).
Pull the handle back as far as it goes. Then let go and see
the cart 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 see
the cart move. Explain what has changed and what has
happened in terms of potential and kinetic energy.



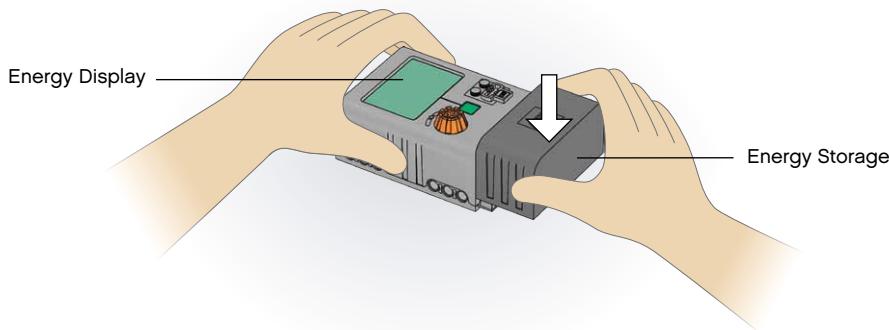


LEGO® Energy Meter

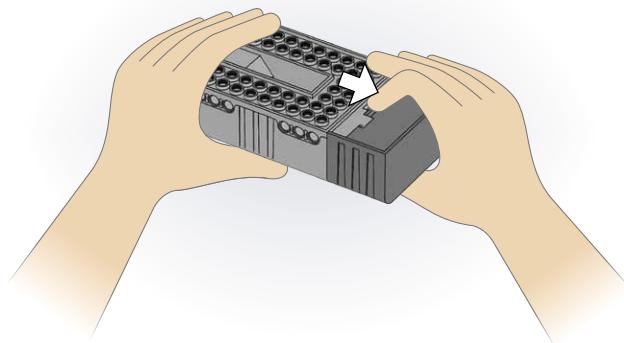
How to get started

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.

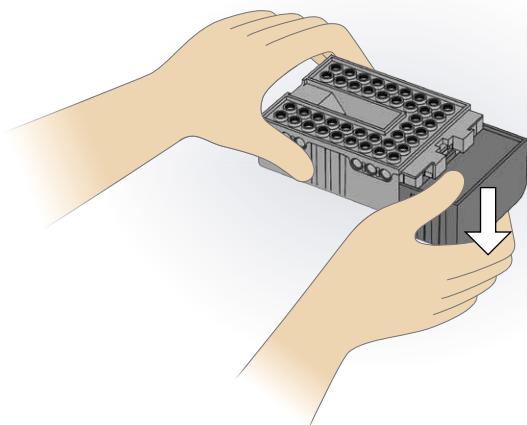
To install the Energy Storage, simply slide it down onto the Energy Display.



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



press the Energy Storage down to slide it off.



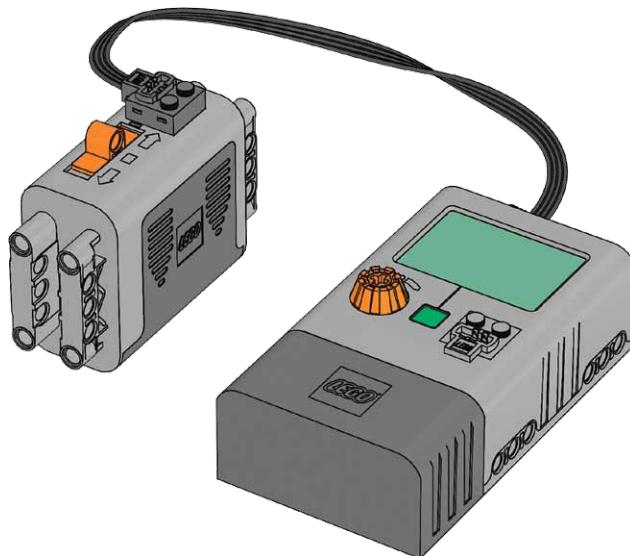
How to charge and discharge the Energy Meter

In order to achieve full capacity on your Energy Storage we recommend that you charge and discharge the Energy Meter three times upon initial use, but also after every 6 months of use or after a long storage period.

To keep full capacity of the Energy Meter and to ensure a long lifetime of the Energy Storage, please follow the charge and discharge procedure as described here.

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. After this the Energy Storage and thereby the Energy Meter is fully charged



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. After this the Energy Storage and thereby the Energy Meter is fully discharged

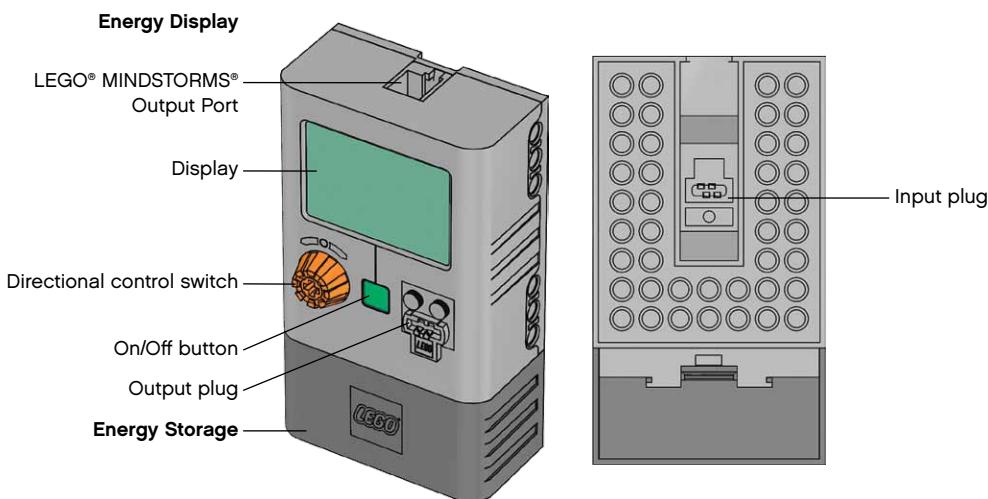
If you wish to cancel the discharge, simply press the On/Off button to turn off the Energy Meter. To return to normal mode, turn on the Energy Meter again.

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.

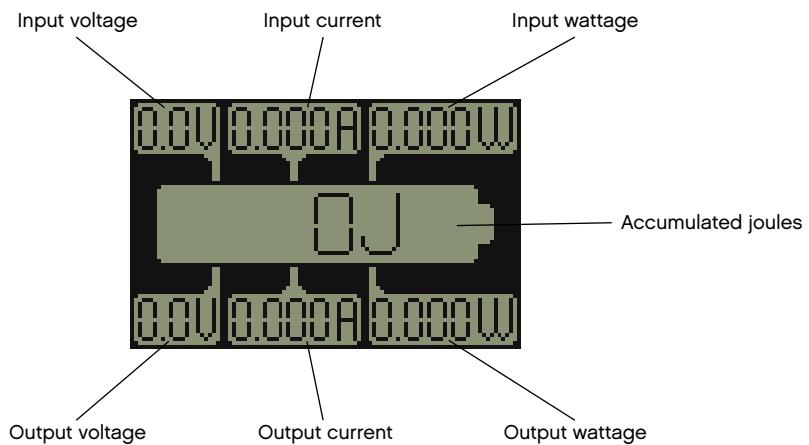
Output plug

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 notice 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 reset 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
- $P = V \times I$, 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
- $P = V \times I$, 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 second. 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



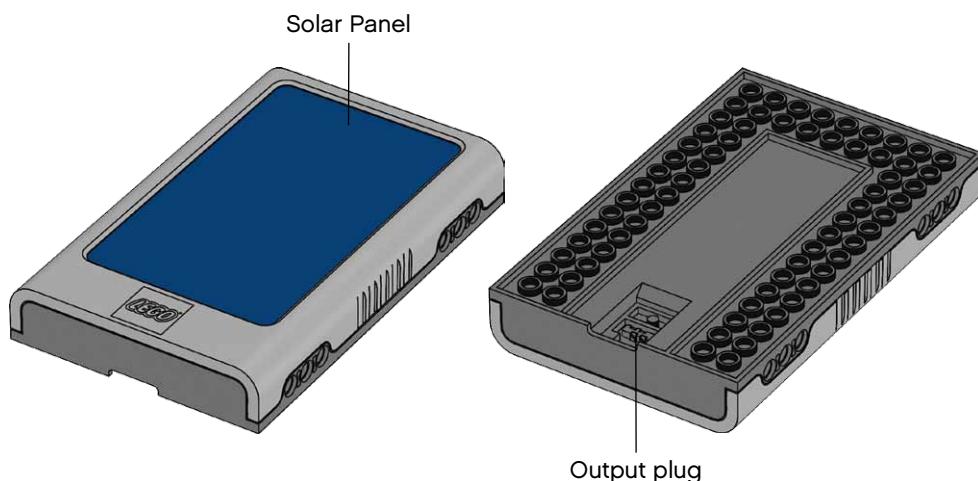
LEGO® Solar Panel

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) 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 from the Solar Panel
- 5 V, 20 mA > at 10,000 lux, 60 W incandescent bulb positioned 8 cm 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) 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

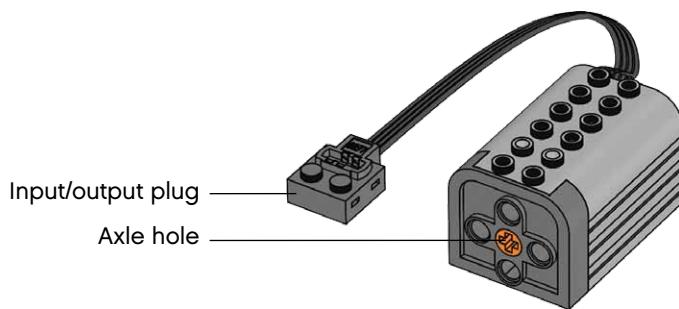


E-Motor

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 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

- Energy accumulation
- Energy consumption
- Energy conversion
- Scientific investigation

Design and technology

- Improvements through technological design
- Assembling components
- Evaluating
- Using mechanisms – gears

Engineering

- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics

- Graphing
- Measuring distance
- Reading measurements
- Timing

Vocabulary

- Efficiency
- Distance
- Joules
- Work

Other materials required

- Graph paper
- Ruler or measuring tape
- Stopwatch or timer

Connect



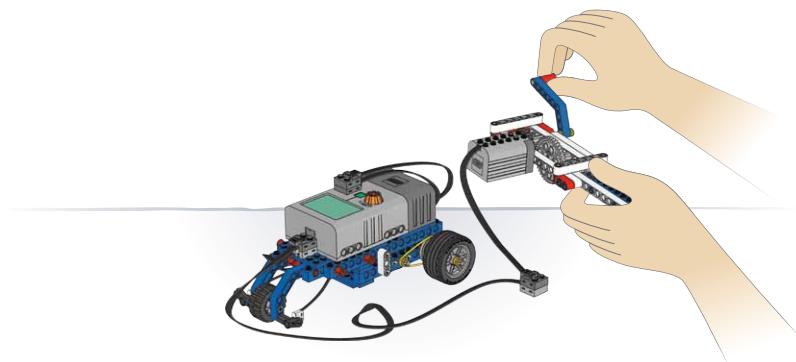
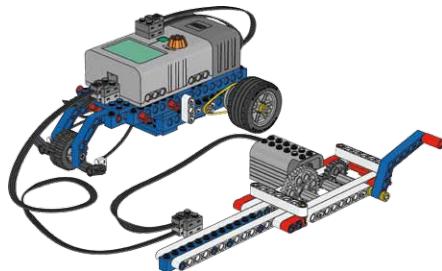
Generators have the ability to convert mechanical energy into electrical energy. The human body can operate a generator by turning the handle. The faster we turn the handle the more electricity we generate.

Now build the Hand Generator and investigate its ability to generate power.

Construct

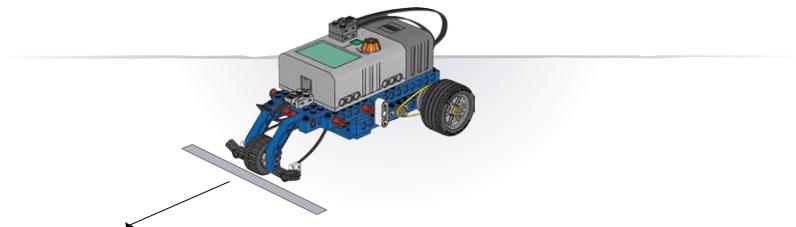
Build the Hand Generator and the Joule Jeep
(Building Instruction booklet 1A and 1B, to page 15 step 16).

- 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 travelled by the Joule Jeep will vary depending on the amount of accumulated joules.

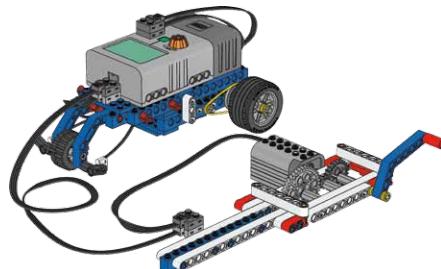
Have students reflect on their investigations by asking questions, such as:

- 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 Instruction booklet 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.

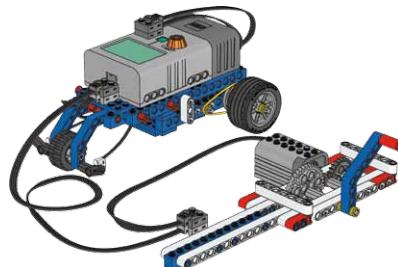
Next, have students find out how far the Joule Jeep can run on the amount of accumulated joules.

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

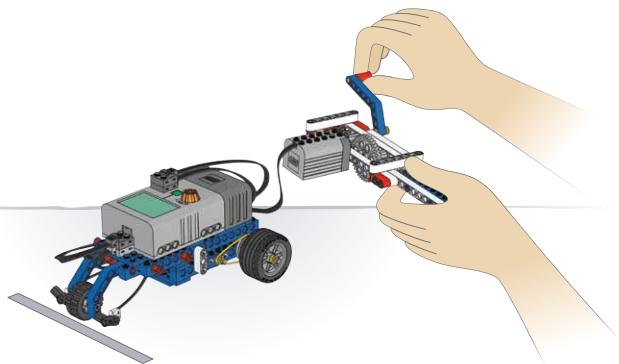
Name(s): _____

Date and subject: _____

Build the Hand Generator and the Joule Jeep

(Building Instruction booklet 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.).

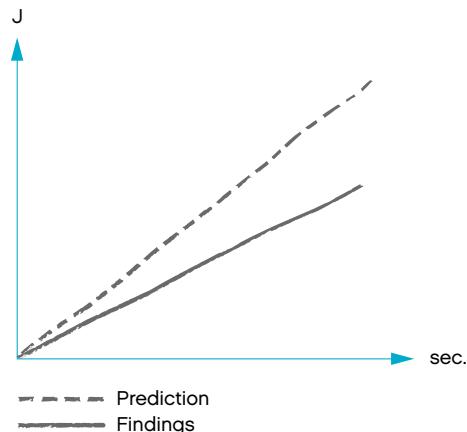
Graph your prediction in a system of coordinates as illustrated opposite.

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 travelled 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 Instruction booklet 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.).

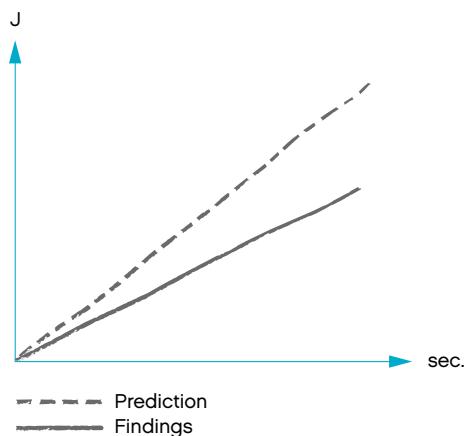
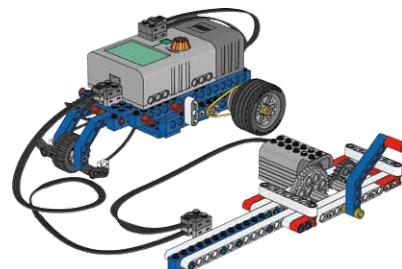
Graph your prediction in a system of coordinates as illustrated opposite.

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 travelled 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.



Solar Station

Science

- Energy conversion
- Energy transfer
- Scientific investigation

Design and technology

- Improvements through technological design
- Assembling components
- Evaluating

Engineering

- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics

- Angles
- Graphing
- Measuring distance
- Reading measurements

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
- Tin 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.

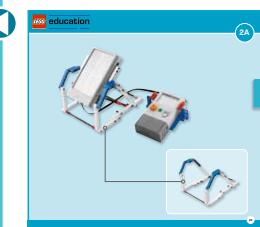
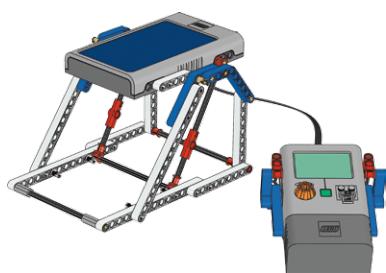
Now build the Solar Station and investigate its ability to generate power.

Construct

Build the Solar Station

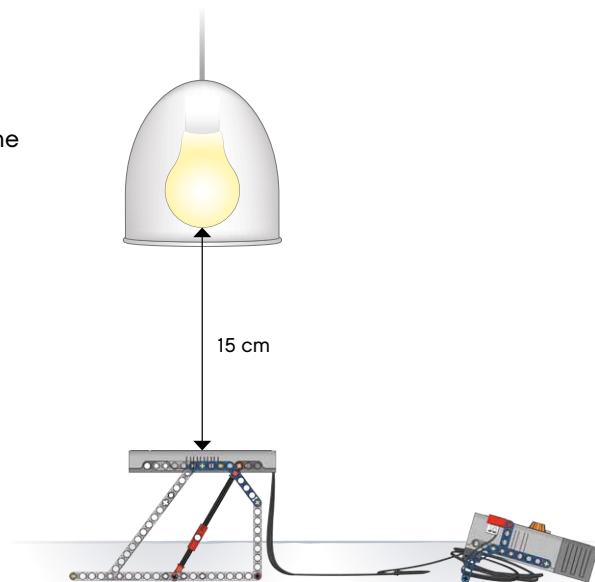
(Building Instruction booklet 2A and 2B, to page 30 step 15).

- 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 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 centre of the light source. Optimally the lamp's 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 centre of the light bulb



Warning!

Heat can damage the Solar Panel. Keep a distance of at least 8 cm 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.

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 colour 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.

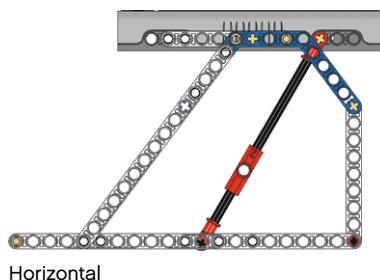
Have students reflect on their investigations by asking questions such as:

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

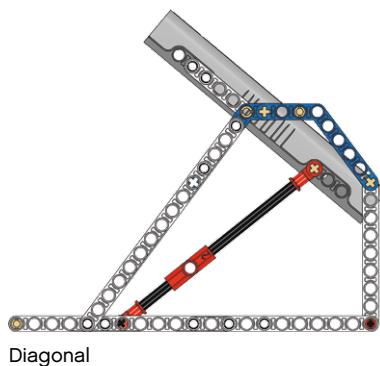
The intensity of the light is at a maximum when the light source is perpendicular to the Solar Panel. As the intensity of light on the surface of the Solar Panel decreases, the voltage, and in particular the current, also decreases.

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

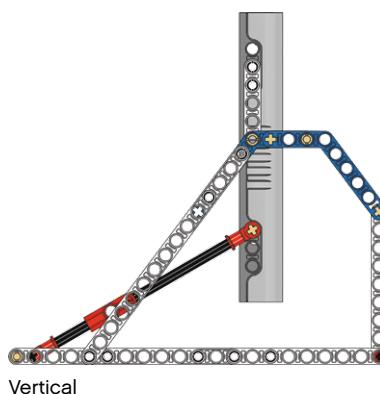
Students need to investigate several times to make sure findings are consistent, that the Solar Station always stays in the same position and at the same distance from the light source.



 **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 optimise the Solar Station to maximise the amount of power (W) produced. Have students record findings and describe which variables have been altered.

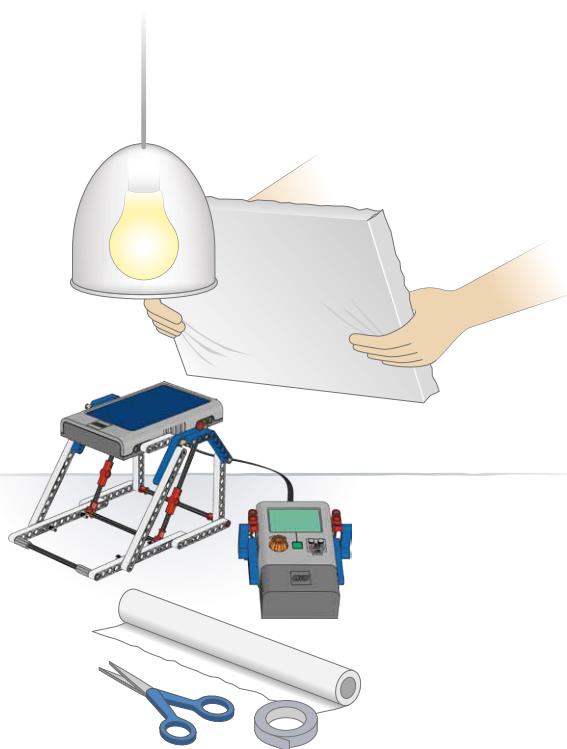
We suggest increasing the wattage of the lamp; one could also use a mirror to reflect the light onto the Solar Station and another underneath the Solar Station to reflect the light back. Instead of a mirror, wrap tin foil around the lid of the basis set as a reflector.

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

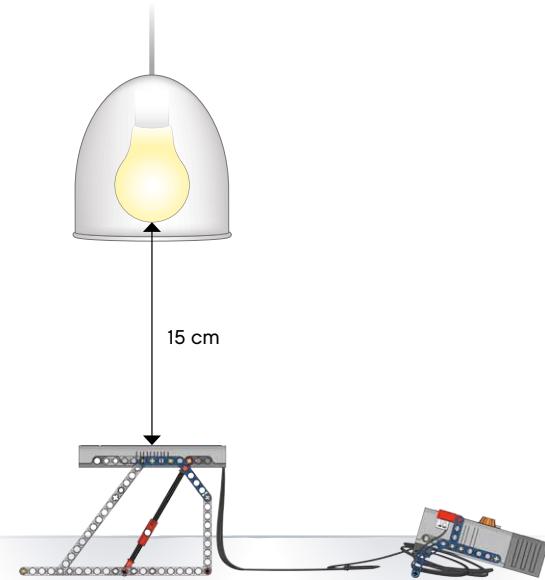
Name(s): _____

Date and subject: _____

Build the Solar Station

(Building Instruction booklet 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 centre of the light source

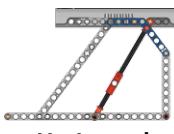
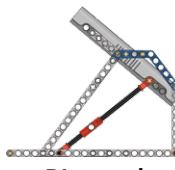
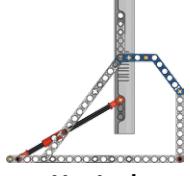


Changing angles

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. 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.

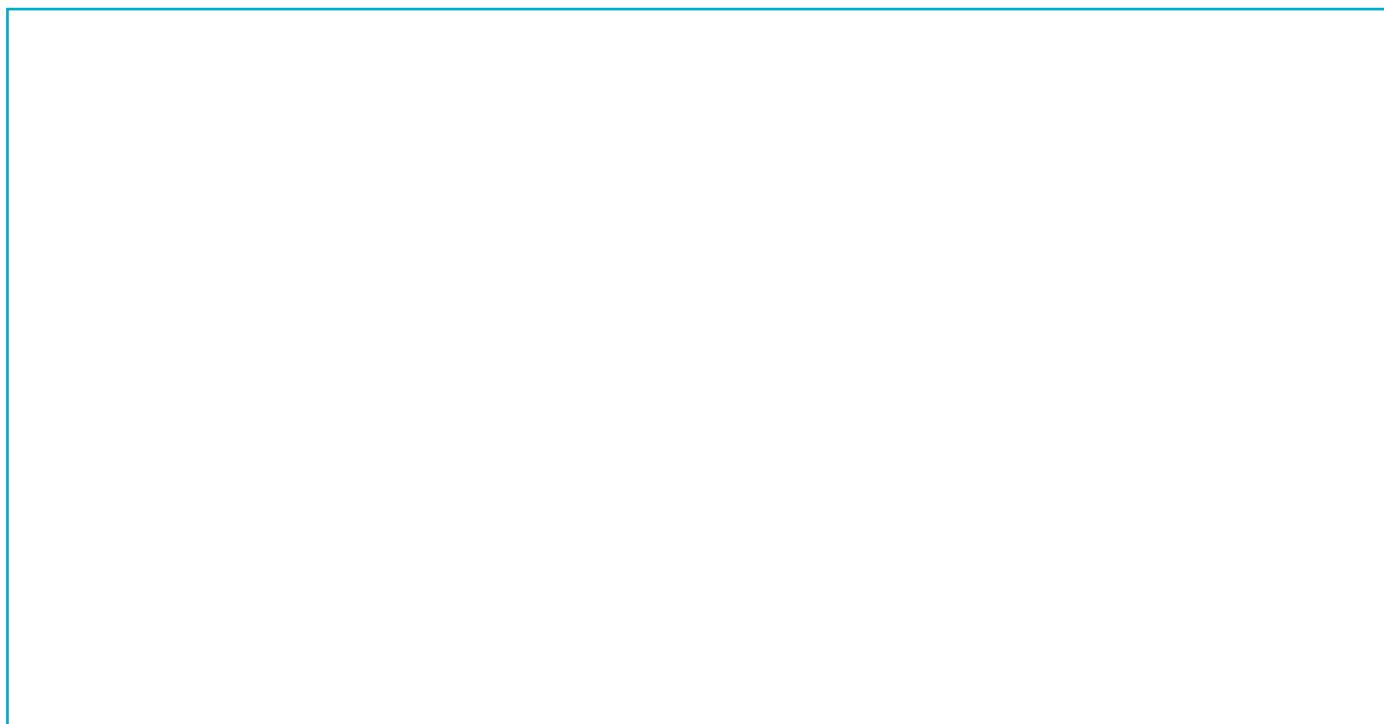
	 Horizontal	 Diagonal	 Vertical
My prediction of V	(V)	(V)	(V)
My prediction of A	(A)	(A)	(A)
My average findings of V	(V)	(V)	(V)
My average findings of A	(A)	(A)	(A)

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, optimise 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.





Wind Turbine

Science

- Energy accumulation
- Energy conversion
- Scientific investigation

Design and technology

- Improvements through technological design
- Assembling components
- Evaluating

Engineering

- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics

- Measuring distance
- Reading measurements

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.

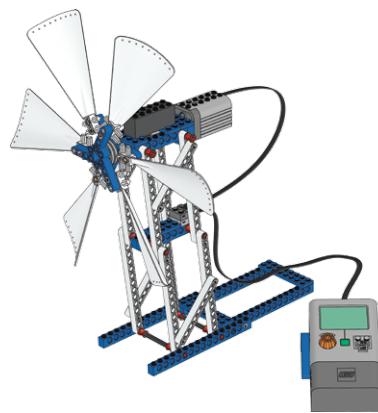
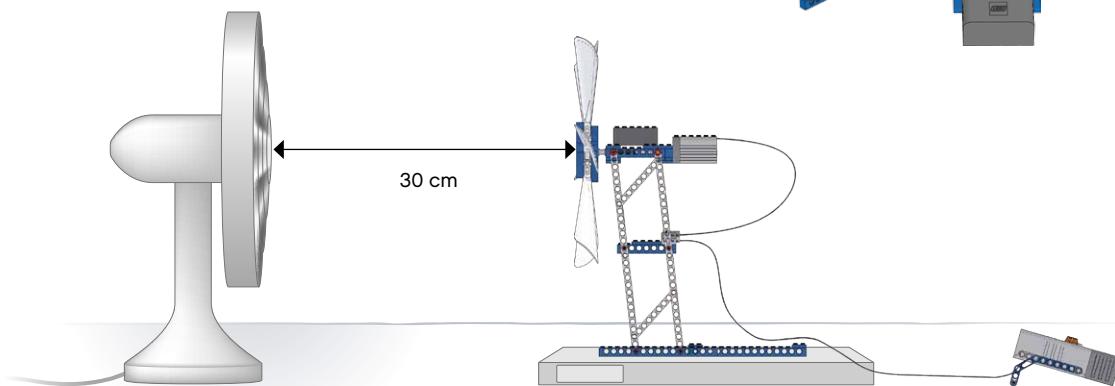
Now build the Wind Turbine and investigate its ability to generate power.

Construct

Build the Wind Turbine

(Building Instruction booklet 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 centre of the fan to the centre of the Wind Turbine with a distance of 30 cm 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.

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. 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.

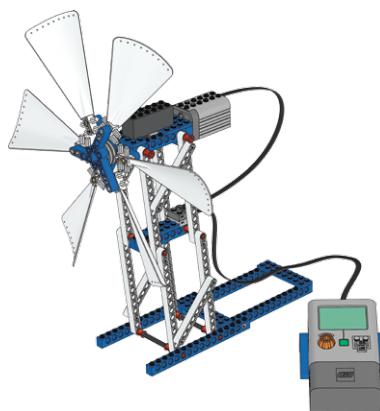
Have students reflect on their investigations by asking questions such as:

- 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 Instruction booklet 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.

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

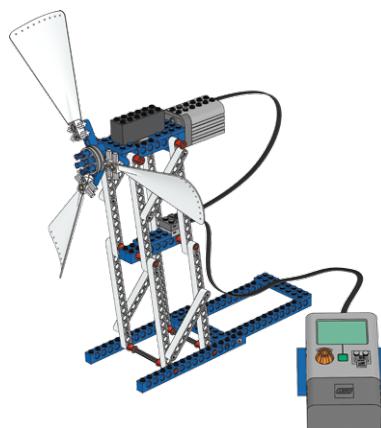
Next, have students turn off the fan and change the distance to 15 cm. Follow the same procedure as described above.

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 centre of the fan and Wind Turbine and the force of the wind. The efficiency of the E-Motor (e.g. the turbine) 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 Turbines 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): _____

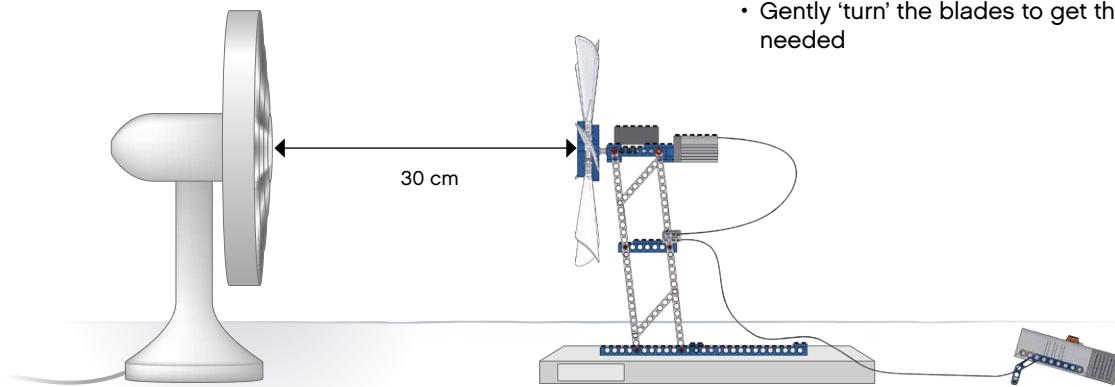
Date and subject: _____

Build the Wind Turbine

(Building Instruction booklet 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 centre of the fan to the centre 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.

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. Follow the same procedure as described above.

	30 cm		15 cm	
My prediction	(V)	(W)	(V)	(W)
My average findings	(V)	(W)	(V)	(W)

Three blades and changing the distance

(Building Instruction booklet 3A and 3B, to page 44 step 1).

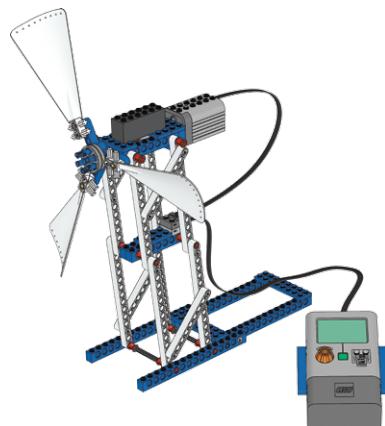
Turn off the fan and remove three blades from the Wind Turbine.

First, predict the voltage (V) and power (W) generated by the Wind Turbine at a distance of 30 cm.

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. Follow the same procedure as described above.



	30 cm	15 cm		
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.



Hydro Turbine

Science

- Energy accumulation
- Energy conversion
- Scientific investigation

Design and technology

- Improvements through technological design
- Assembling components
- Evaluating

Engineering

- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics

- Graphing
- Measuring distance
- Reading measurements
- Timing

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
- Tea towels or tissue paper 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.

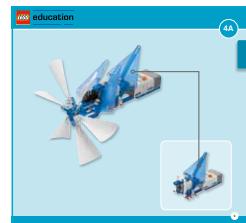
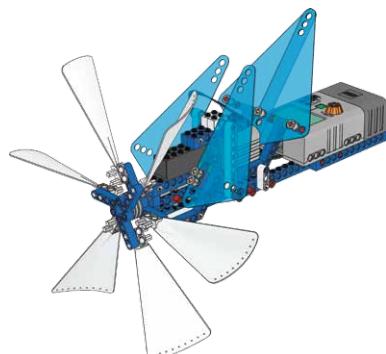
Now build the Hydro Turbine and investigate its ability to generate power.

Construct

Build the Hydro Turbine

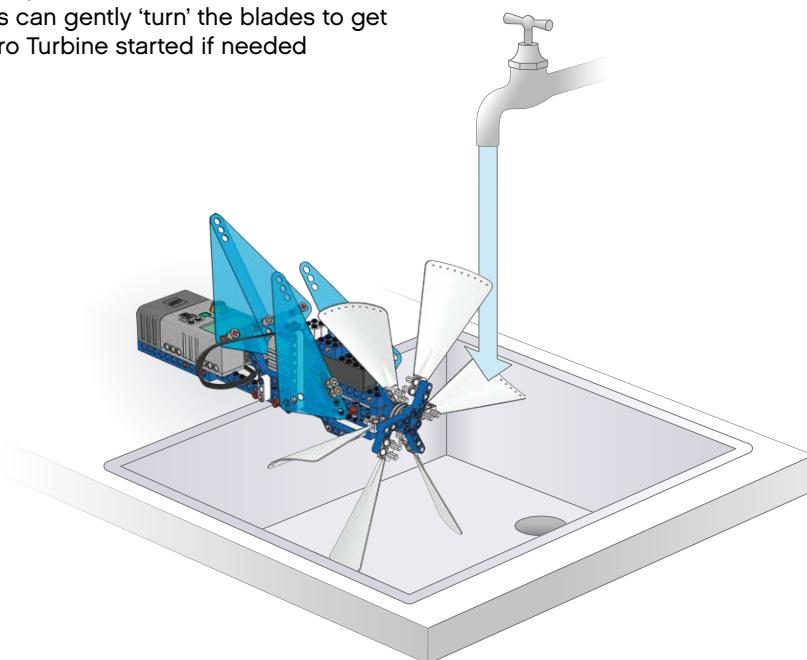
(Building Instruction booklet 4A and 4B, to page 20 step 30).

- 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 tea towels or tissue paper 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 film 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.

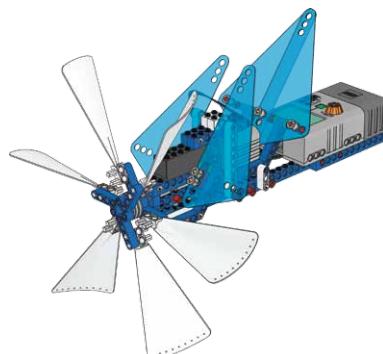
Have students reflect on their investigations by asking questions such as:

- 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 anti-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 Instruction booklet 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.

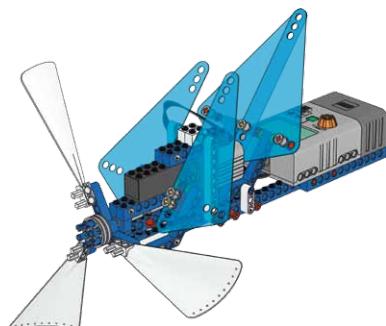
Before taking any readings, make sure students let the Hydro Turbine run for a while to pick up speed.

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

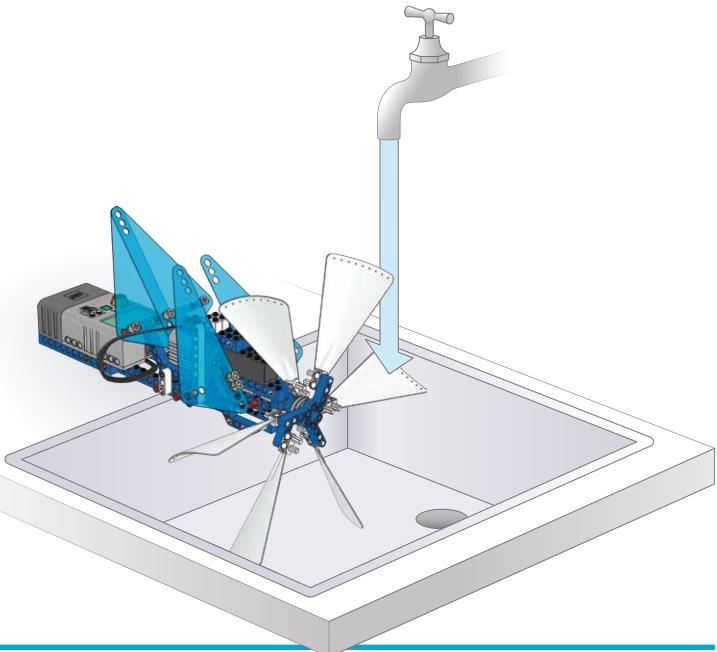
Name(s): _____

Date and subject: _____

Build the Hydro Turbine

(Building Instruction booklet 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

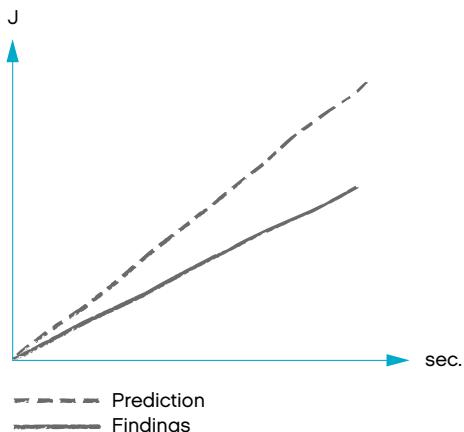


Accumulating joules

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

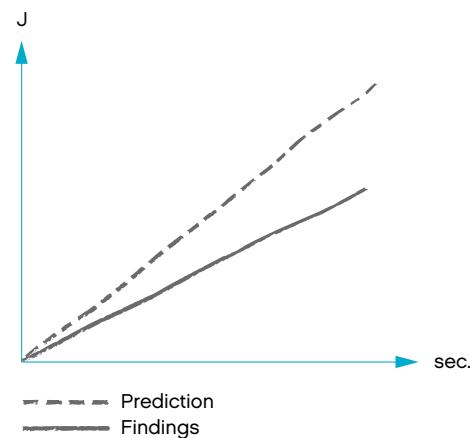
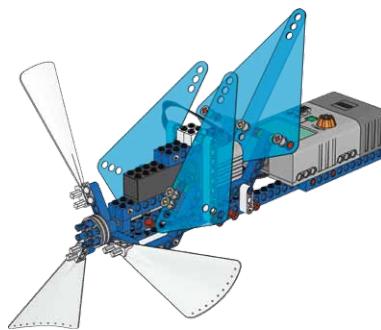
(Building Instruction booklet 4A and 4B, to page 22 step 2).

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.



Solar Vehicle

Science

- Energy conversion
- Energy transfer
- Forces and motion
- Scientific investigation

Design and technology

- Improvements through technological design
- Assembling components
- Evaluating
- Using mechanisms – gears, wheels and axles

Engineering

- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics

- Calculating speed
- Measuring distance
- Reading measurements
- Timing

Vocabulary

- Efficiency
- LEGO® Solar Panel
- Speed

Other materials required

- A smooth flat track surface at least 150 cm 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

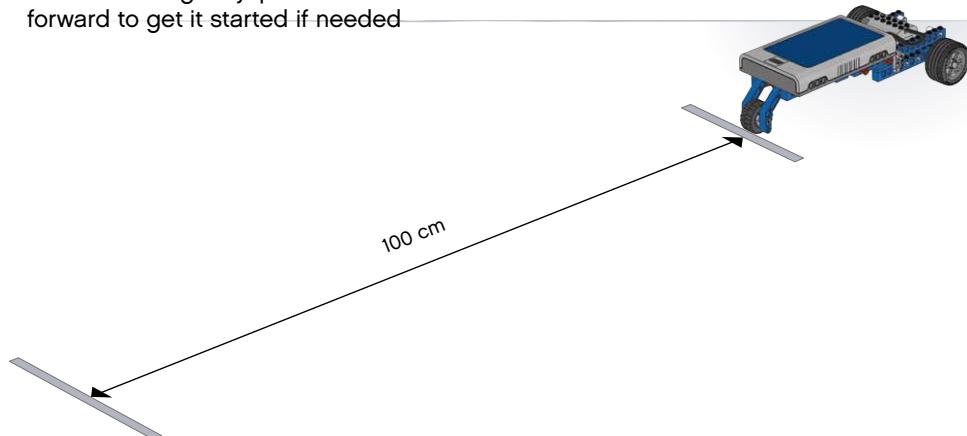
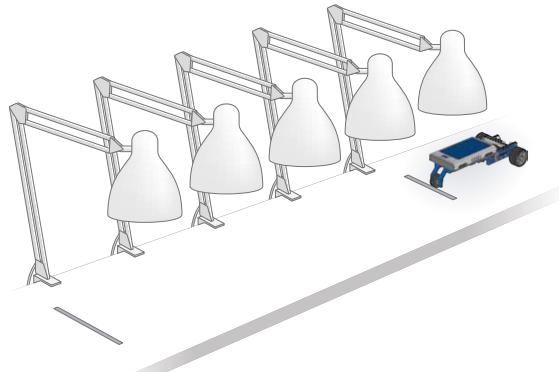
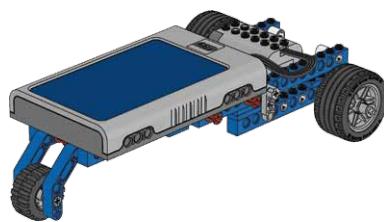
Build the Solar Vehicle

(Building Instruction booklet 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 centre 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 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 centre of the light bulb
- Mark a start line and finish line 100 cm 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 from the Solar Panel to the light source at all times. Make sure students handle light bulbs with great care!



Contemplate

Travelling with different gear ratios

The task requires students to investigate the speed of the Solar Vehicle travelling 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 travelling 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:

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

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 Instruction booklet 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.

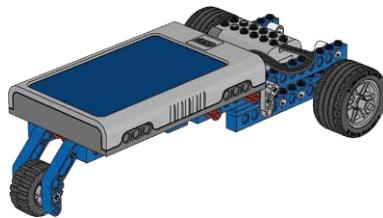
Have students reflect on their investigations by asking questions such as:

- 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

Travelling with smaller wheels

(Building Instruction booklet 5A and 5B, to page 44 step 6).

The task requires students to investigate the speed of the Solar Vehicle travelling 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 travelling 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 axle speed is the same, due to the larger circumference of the larger wheels.

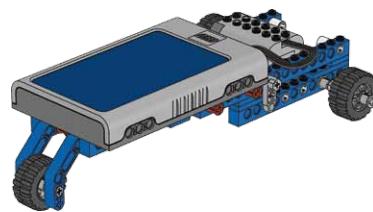
Identifying variables

Have students identify and write down at least three variables, explaining clearly how these affect the Solar Vehicles 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 optimise conditions for the Solar Vehicle.



Did you know?

The circumference of the small wheel is 9.6 cm.



The circumference of the large wheel is 13.6 cm



Solar Vehicle

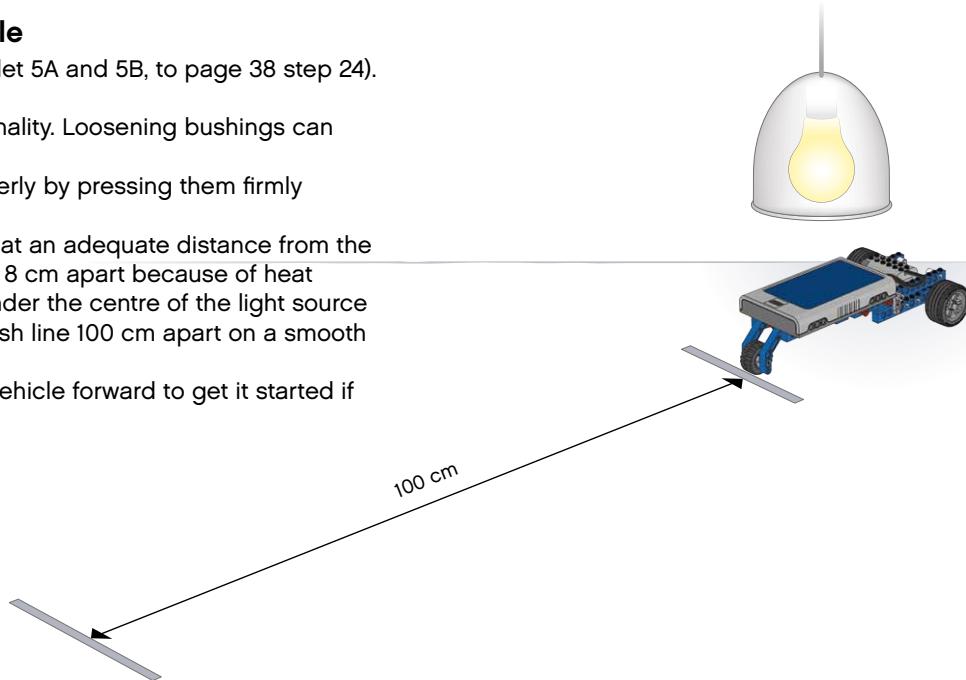
Name(s): _____

Date and subject: _____

Build the Solar Vehicle

(Building Instruction booklet 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 apart because of heat
- Place the Solar Panel under the centre of the light source
- Mark a start line and finish line 100 cm apart on a smooth flat surface
- Gently 'push' the Solar Vehicle forward to get it started if needed



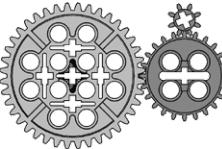
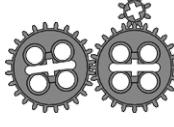
Travelling with different gear ratios

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:

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

Next, rebuild the Solar Vehicle and follow the same procedure for the new Solar Vehicle with a gearing of 3:1. (Building Instruction booklet 5A and 5B, to page 42 step 4).

		
My prediction	sec.	sec.
My findings	sec.	sec.
My calculations	(m/s)	(m/s)

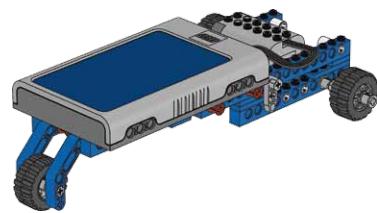
Travelling with smaller wheels

(Building Instruction booklet 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.



Boat Pulley

Science

- Energy consumption
- Energy efficiency
- Energy transfer
- Scientific investigation

Design and technology

- Improvements through technological design
- Assembling components
- Evaluating
- Using mechanisms – pulleys

Engineering

- Engineering design
- Identifying energy
- Investigating and evaluating variables

Mathematics

- Calculating efficiency
- Calculating measurements
- Measuring distance
- Reading measurements

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.

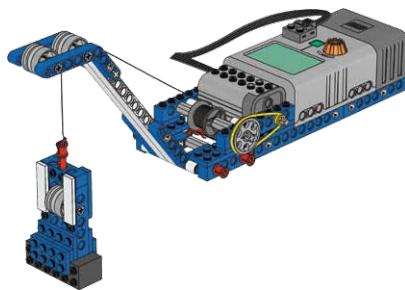
Now build the Boat Pulley and investigate the influence of pulley systems on the power needed to lift the load.

Construct

Build the Boat Pulley

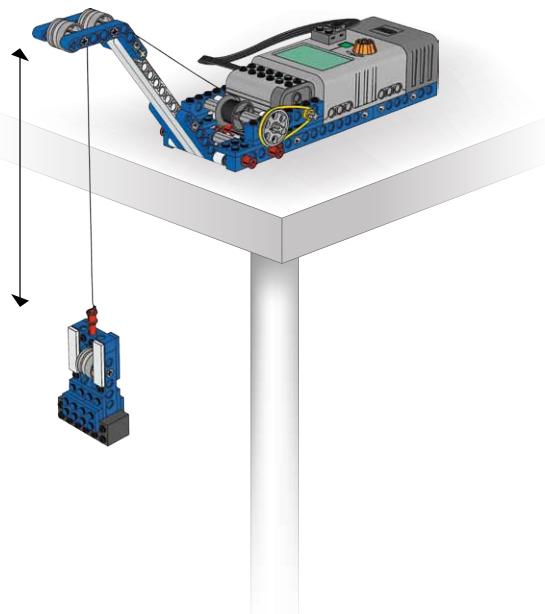
(Building Instruction booklet 6A and 6B, to page 63 step 26).

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

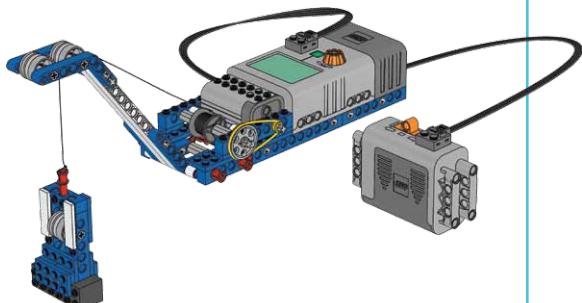


Test setting

- 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 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 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 load and have students follow the same procedure now with two fixed and one movable pulley. (Building Instruction booklet 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.

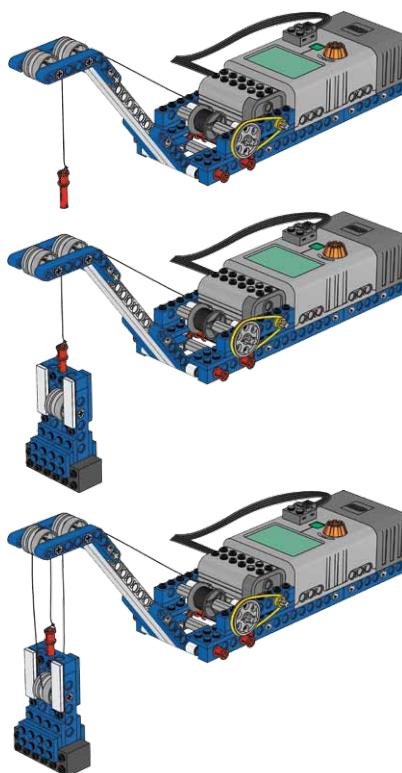
Have students reflect on their investigations by asking questions such as:

- 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.

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

$$\text{Work (J)} = \text{Force (N)} \times \text{Distance (m)}$$

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:

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

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:

$$\text{Work} = 0.67 \text{ N} \times 0.6 \text{ m}$$

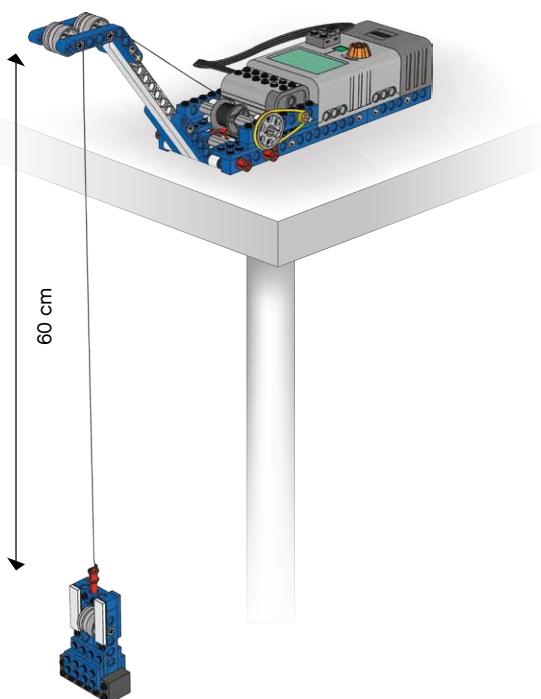
$$\text{Work} = 0.402 \text{ J}$$

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%.

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

$$\text{Efficiency} = 20.1\%$$

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:

$$F = m \times g$$

F is the force, *m* is the mass, measured in kilogram, and *g* is the proportionality constant, which is 9.8 m/s².

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 Pulleys efficiency.

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

Boat Pulley

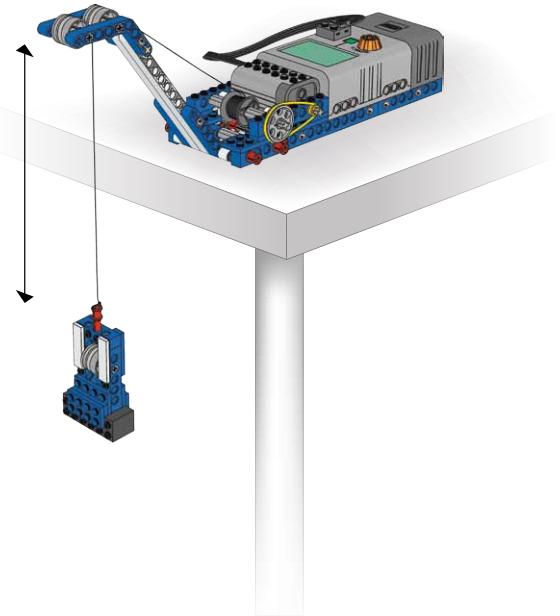
Name(s): _____

Date and subject: _____

Build the Boat Pulley

(Building Instruction booklet 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 Instruction booklet 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.

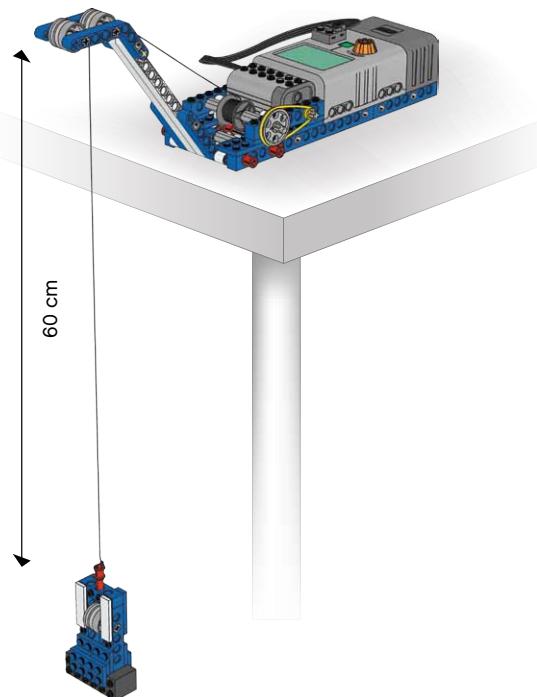
First, calculate the ideal amount of work needed by using this formula:

$$\text{Work (J)} = \text{Force (N)} \times \text{Distance (m)}$$

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:

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



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.

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.

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 Mowers 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?

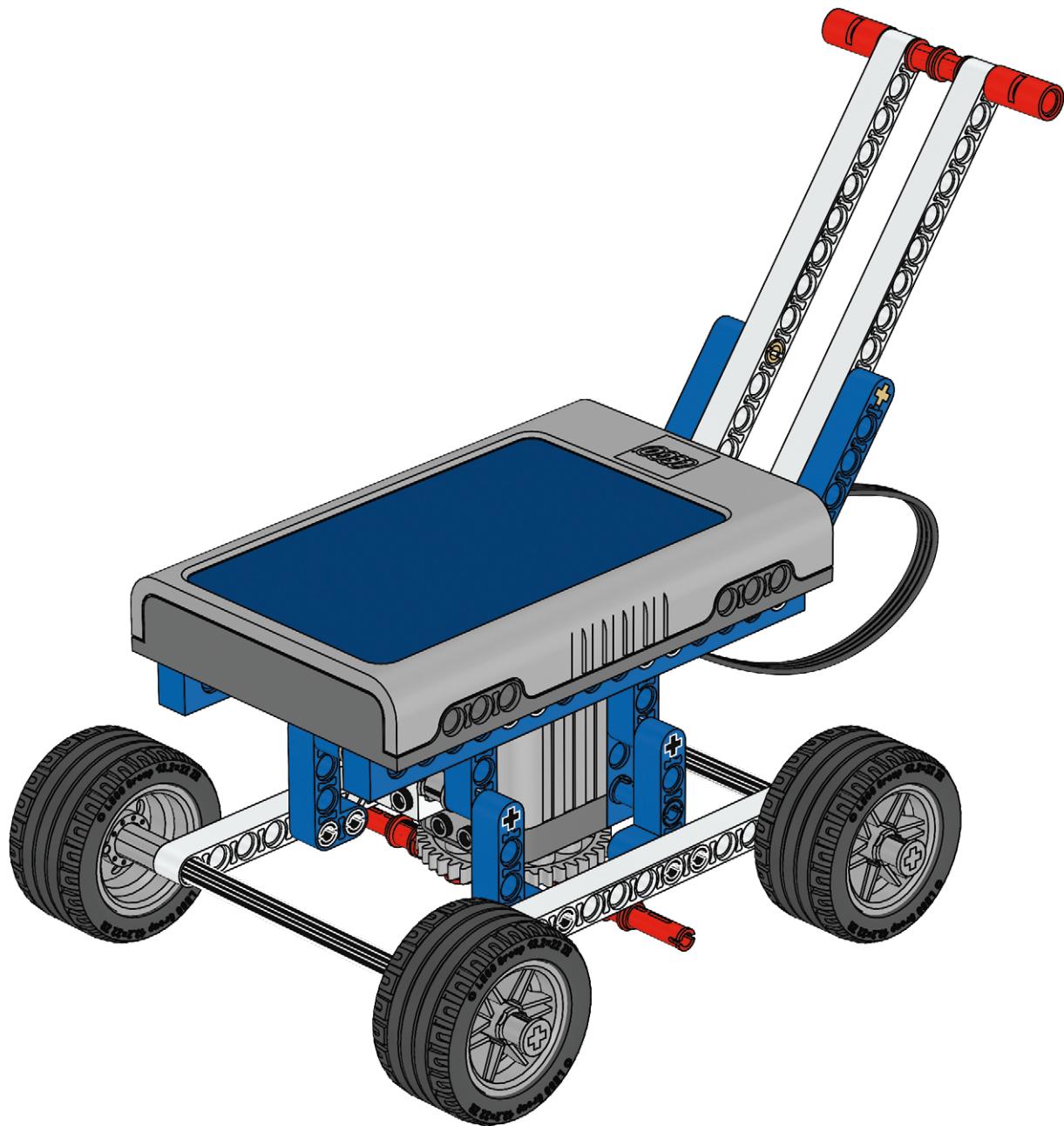
Look at:



Sweeper



Solar Vehicle



Suggested model, prototype solution

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.

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 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?

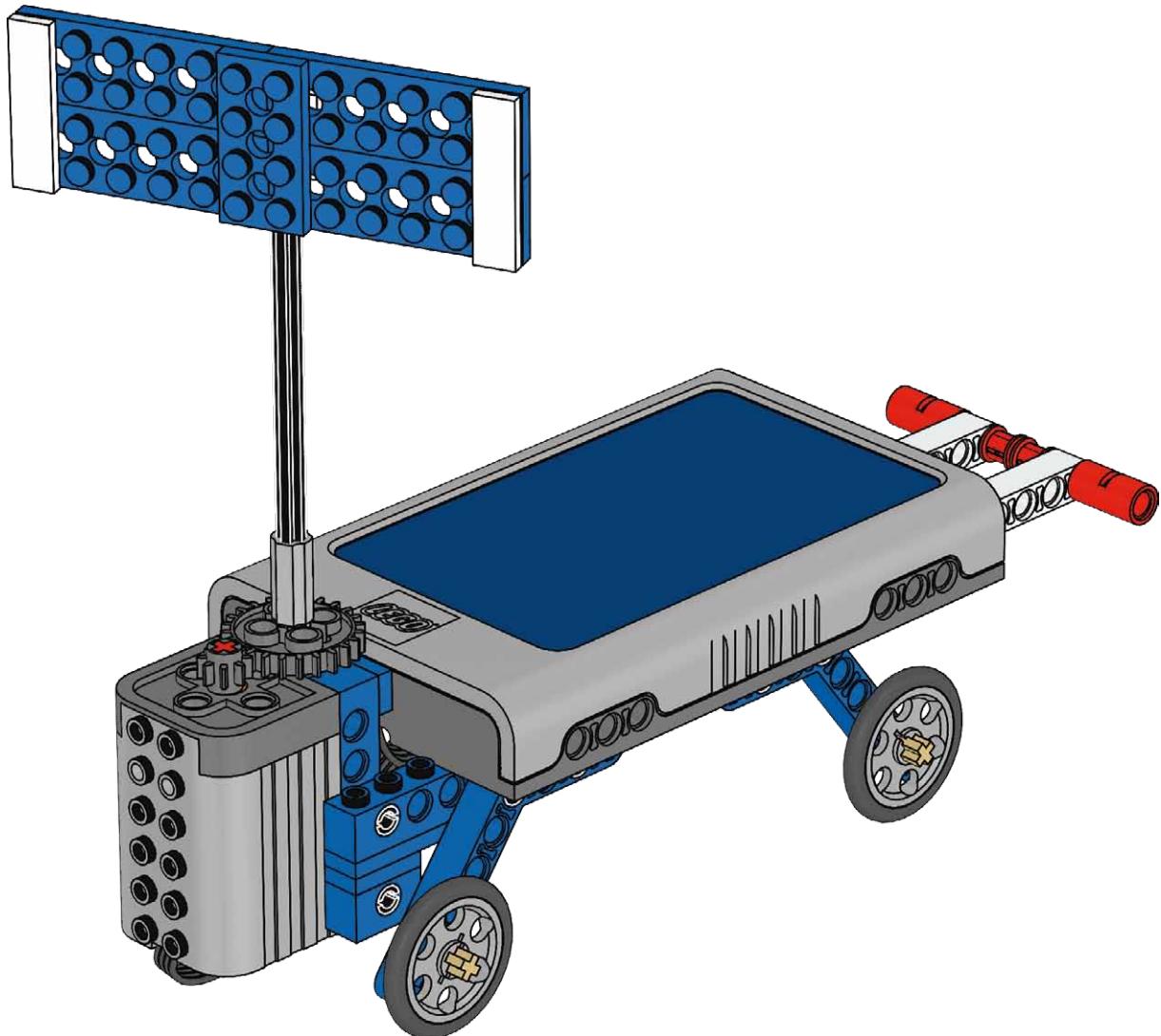
Look at:



Dogbot



Solar Station



Suggested model, prototype solution

Motorised 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 hall 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 motorised fan, powered by a renewable energy source. Make sure it makes the air circulate and is safe to use.

Motorised 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 Motorised 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 Motorised 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 Motorised Fan can circulate air, try rolling small bits of paper together and see if the Motorised 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?

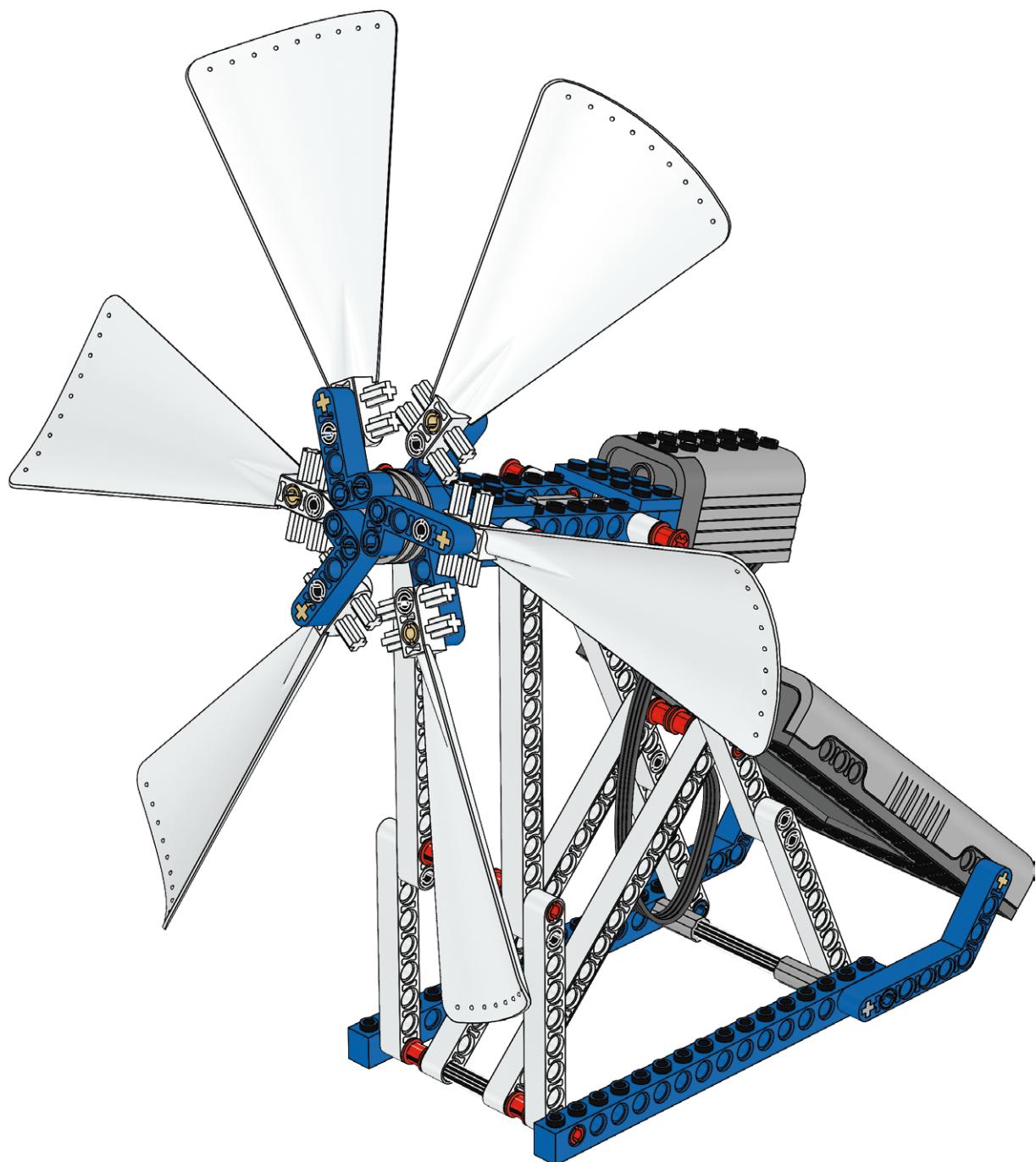
Look at:



Wind Turbine



Solar Station



Suggested model, prototype solution

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.

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?

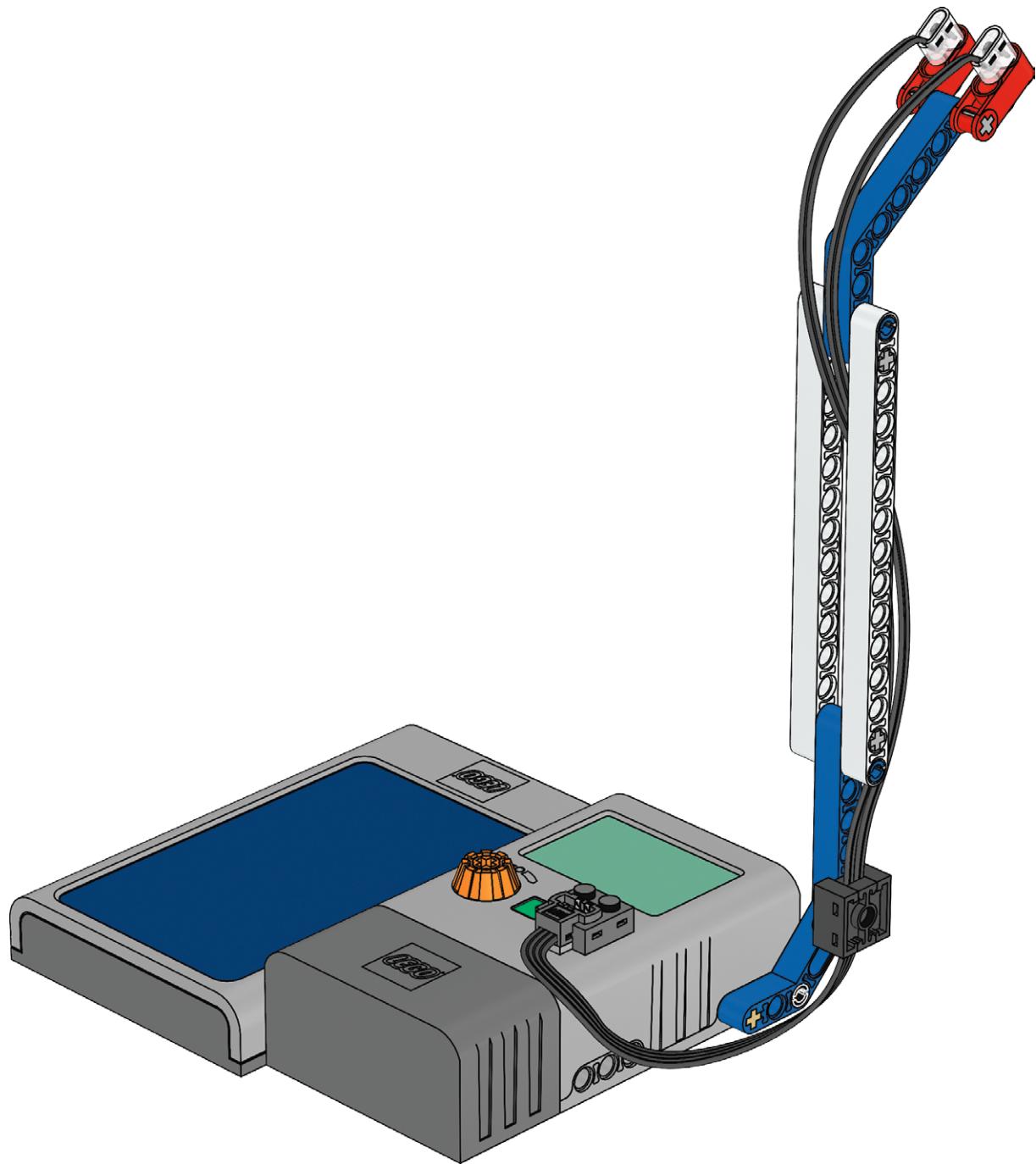
Look at:



Hand Generator



Solar Station



Suggested model, prototype solution



Glossary

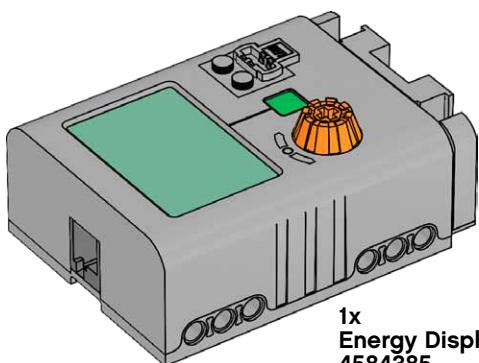
A	Ampere (A)	The SI unit of electrical current. Ampere is the amount of electric charges per second.
B	Barrage	A water channel that is controlled at its head by a gate or a sluice. A barrage is typically an artificial obstruction, designed to either increase a river's depth or to divert its flow. See 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	A 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:
		$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$

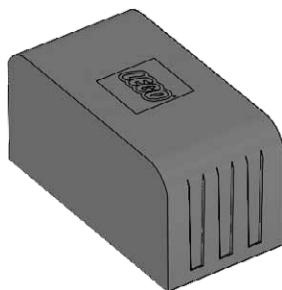
T	Torque	The applied force creating a rotational motion, also called a moment of force.
	Turbine	A rotary machine that extracts energy from steam, water or wind and converts it into useful work.
V	Variable	A quantity that can take on different values or is likely to vary.
	Volt (V)	The SI unit of electromotive force or electrical potential difference, measured in volt (V).
	Voltage	The force driving the flow of electrical energy. Voltage is measured in volt (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 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).



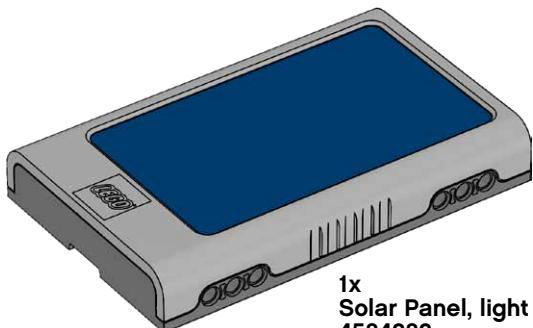
LEGO® Element Survey



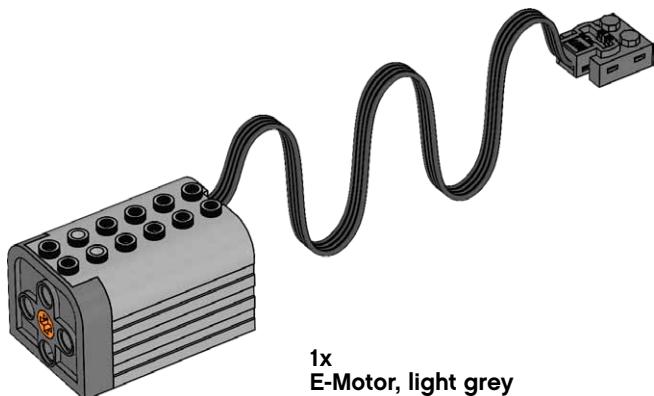
1x
Energy Display, light grey
4584385



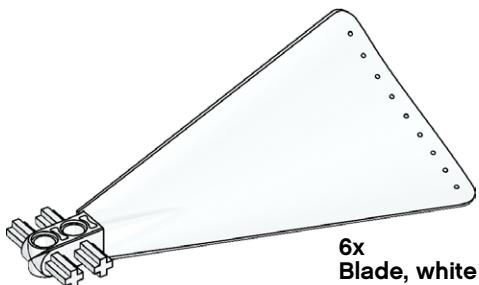
1x
Energy Storage, dark grey
4584386



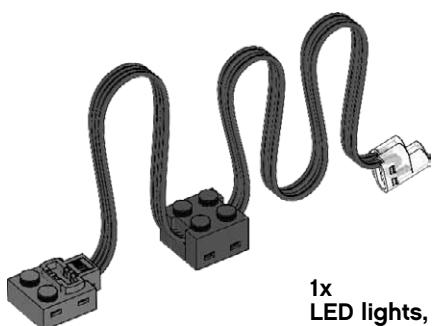
1x
Solar Panel, light grey
4584383



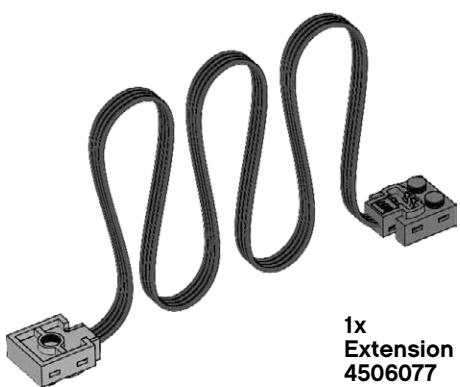
1x
E-Motor, light grey
4584384



6x
Blade, white
4587185



1x
LED lights, white
4546421



1x
Extension Wire, 50cm
4506077

Localisation, translation & DTP: EICOM ApS, Denmark

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