



# Engineering Ups and Downs



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## Lesson Focus

Lesson focuses on the engineering behind elevators. Teams of students explore principles and requirements of vertical travel, then design and construct a working elevator to service a toy car garage using wheels, pulleys, string, cardboard and other materials.

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## Lesson Synopsis

The Engineering Ups and Downs lesson explores the engineering and principles behind working elevators. Student teams explore the history of elevators, their design, and develop their own working elevator using wheels, pulleys, string, cardboard and other materials. Student teams design their toy car garage elevator first on paper, then execute their plan, and evaluate the strategies employed all student teams.

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## Year Levels

Year 7 – Term 2, Year 10 – Term 3

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## Objectives

- ✦ Learn about engineering design.
- ✦ Learn about elevator operations.
- ✦ Learn about teamwork and working in groups.

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## Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- ✦ mechanical engineering and design
- ✦ problem solving
- ✦ teamwork



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## Lesson Activities

Students learn how elevators meet human needs, explore how they work, and then work in teams to develop a design for their own elevator to service a toy car garage. Teams plan their system, using materials provided, draw their design, build it, troubleshoot as needed, evaluate their own work and that of other students, and then present their observations to the class.

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## Resources/Materials

- ✦ Teacher Resource Documents (attached)
- ✦ Student Worksheets (attached)
- ✦ Student Resource Sheets (attached)

### Engineering Ups and Downs

Developed by IEEE as part of TryEngineering  
[www.tryengineering.org](http://www.tryengineering.org)

Modified and aligned to  
Australian Curriculum by  
Queensland Minerals and  
Energy Academy

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## Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

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## Internet Connections

- ✦ TryEngineering ([www.tryengineering.org](http://www.tryengineering.org))
- ✦ Otis Worldwide ([www.otisworldwide.com](http://www.otisworldwide.com))
- ✦ Online History of Otis Elevators ([www.otisworldwide.com/d31-timeline.html](http://www.otisworldwide.com/d31-timeline.html))
- ✦ The Elevator Museum ([www.theelevatormuseum.org](http://www.theelevatormuseum.org))
- ✦ Curriculum Links ([www.acara.edu.au](http://www.acara.edu.au))



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## Recommended Reading

- ✦ Up, Down, Across: Elevators, Escalators, and Moving Sidewalks (ISBN: 1858942136)
- ✦ Vertical Transportation 3E (ISBN: 0471162914)

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## Optional Writing Activity

- ✦ The invention of elevators has had a huge impact on civil engineering and urban planning. Write an essay or a paragraph about how you think the invention of the elevator has impacted the skyline of the town or city in which you live.

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## For Teachers: Teacher Resource

### ◆ Lesson Goal

The Engineering Ups and Downs lesson explores the engineering and principles behind working elevators. Students explore the history of elevators, their design, and develop their own working elevator for a toy car garage using wheels, pulleys, string, cardboard and other materials. Student teams design their elevator first on paper, then execute their plan, and evaluate the strategies employed all student teams.

### ◆ Lesson Objectives

- ✦ Learn about engineering design.
- ✦ Learn about elevator operations.
- ✦ Learn about teamwork and working in groups.

### ◆ Materials

- ✦ Student Resource Sheet
- ✦ Student Worksheets
- ✦ One set of materials for each group of students:
  - Glue
  - String
  - Paperclips
  - Paper
  - Pencils
  - Cardboard
  - cardboard tubes (such as from paper towel or toilet paper rolls)
  - markers
  - pulleys or thread spools (3)
  - thin rope, string or fishing line
  - cardboard box to serve as elevator room (shoe box, large milk carton)
  - small toy cars.



### ◆ Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework. Divide students into groups of 2-3 students, providing a set of materials per group.
2. Explain that students are now an "engineering" team that must develop a hand powered elevator to deliver toy cars to a three story parking garage. (you may wish to require a certain weight for each load, or determine that each car is a similar weight). The elevators must be able to securely stop at each floor and lift a toy car of a set weight.
3. Students meet and develop a plan for their elevator system. They agree on materials they will need (out of those you have provided), write or draw their plan, and then present their plan to the class.
4. Student groups next execute their plans. They may need to rethink their plan, add materials, or start over.
5. Each student group evaluates the results, completes an evaluation/reflection worksheet, and presents their findings to the class.

◆ **Tips**

To speed up the construction process, you may wish to create the three level "garage" first, and then simply have each team move their elevator to the garage for testing. This will eliminate the need for each team to make the garage themselves. Garages can be three shoeboxes taped together, or some other simple structure. Also, if students glue any part of their elevator system, it may require an overnight drying period.

◆ **Time Needed**

Two to four 45 minute sessions



# Engineering Ups and Downs

## Student Resource: The History of Elevators

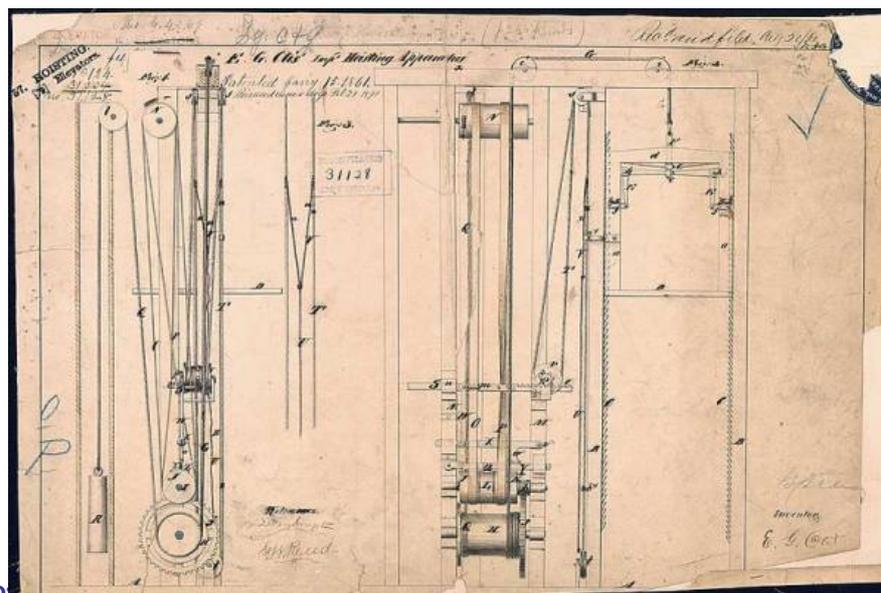
### ◆ Elevator History

An elevator or lift is a transport device used to move goods or people vertically. The first reference about the elevator is located in the works of the Roman architect Vitruvius, who reported that Archimedes built his first lift or elevator, probably, in 236 B.C. In some literary sources of later historical period lifts were mentioned as cabs, on the hemp rope and powered by hand or by animal's force. In 1853, Elisha Otis introduced the safety elevator, which prevented the fall of the cab if the cable broke. The design of the OTIS safety is somewhat similar to one type still used today. The safety elevator used a special mechanism to lock the elevator car in place should the hoisting ropes fail. Otis made skyscrapers possible by providing safe mechanical transport to upper floors.



### ◆ Otis and Other Manufacturers

On March 23, 1857 the first Otis elevator was installed at 488 Broadway in New York City. The first elevator shaft preceded the first elevator by four years. Construction for Peter Cooper's Cooper Union building in New York began in 1853. An elevator shaft was included in the design for Cooper Union, because Cooper was utterly confident a safe passenger elevator would soon be invented; the shaft however was circular because Cooper felt it was the most efficient design. Later Otis designed a special elevator for the school. Today the Otis Elevator Company, now a subsidiary of United Technologies Corporation, is the world's largest manufacturer of vertical transport systems, followed by Schindler, Thyssen-Krupp, Kone, and Fujitec. According to United Technologies, Otis elevators carry the equivalent of the world's population every nine days. The following is Elisha Otis's Elevator Patent Drawing, 01/15/1861.



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## Student Resource: The History of Elevators (continued)

### ◆ Types of Elevators

In general, there are three means of moving an elevator:

1. Traction elevators: Geared Traction machines are driven by AC or DC electric motors. Geared machines use worm gears to control mechanical movement of elevator cars by "rolling" steel hoist ropes over a drive sheave which is attached to a gearbox driven by a high speed motor. A brake is mounted between the motor and drive sheave (or gearbox) to hold the elevator stationary at a floor. The grooves in the drive sheave are specially designed to prevent the cables from slipping. "Traction" is provided to the ropes by the grip of the grooves in the sheave, thereby the name. As the ropes age and the traction grooves wear, some traction is lost and the ropes must be replaced and the sheave repaired or replaced.



2. Hydraulic elevators: Conventional Hydraulic elevators were first developed by Dover Elevator (now ThyssenKrupp Elevator). They are quite common for low and medium rise buildings (2-10 floors) and use a hydraulically powered plunger to push the elevator upwards. On some, the hydraulic piston (plunger) consists of telescoping concentric tubes, allowing a shallow tube to contain the mechanism below the lowest floor. On others, the piston requires a deeper hole below the bottom landing, usually with a PVC casing (also known as a caisson) for protection

3. Climbing elevator: A climbing elevator is a self-ascending elevator with its own propulsion. The propulsion can be done by an electric or a combustion engine. Climbing elevators are used in guyed masts or towers, in order to make easy access to parts of these constructions, such as flight safety lamps for maintenance.

### ◆ Did You Know?

-- The elevator in the new city hall in Hanover, Germany is a technical rarity, and unique in Europe, as the elevator starts straight up but then changes its angle by 15 degrees to follow the contour of the dome of the hall.

-- A small freight elevator is often called a dumbwaiter, often used for the moving of small items such as dishes in a 2-storey kitchen or books in a multi-story rack assembly.

Dumbwaiters, especially older ones, may also be hand operated using a roped pulley, and they are often found in Victorian-era houses, offices and other establishments when such devices were at their peak.



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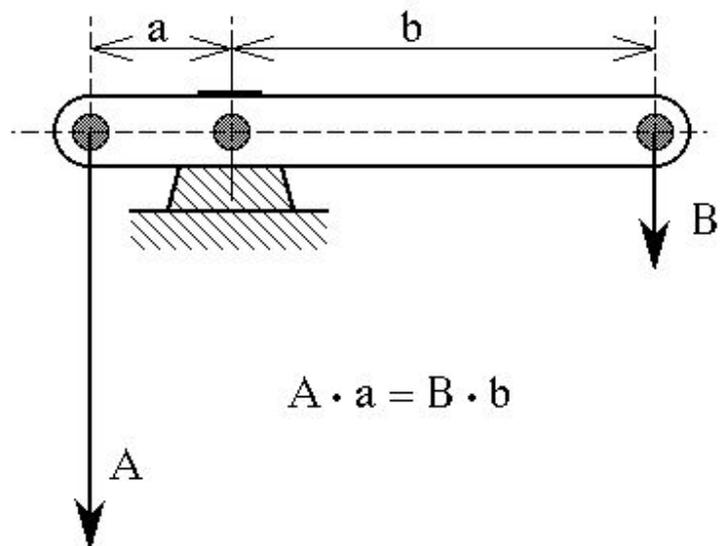


## Student Resource: Mechanical Advantage

### ◆ What is Mechanical Advantage

In physics and engineering, mechanical advantage (MA) is the factor by which a mechanism multiplies the force put into it. Following are simple machines where the mechanical advantage is calculated.

The beam shown is in static equilibrium around the fulcrum. This is due to the moment created by vector force "A" counterclockwise (moment  $A \cdot a$ ) being in equilibrium with the moment created by vector force "B" clockwise (moment  $B \cdot b$ ). The relatively low vector force "B" is translated in a relatively high vector force "A". The force is thus increased in the ratio of the forces  $A : B$ , which is equal to the ratio of the distances to the fulcrum  $b : a$ . This ratio is called the mechanical advantage. This idealized situation does not take into account friction.



**Wheel and axle:** A wheel is essentially a lever with one arm the distance between the axle and the outer point of the wheel, and the other the radius of the axle. Typically this is a fairly large difference, leading to a proportionately large mechanical advantage. This allows even simple wheels with wooden axles running in wooden blocks to still turn freely, because their friction is overwhelmed by the rotational force of the wheel multiplied by the mechanical advantage.

**Pulley:** Pulleys change the direction of a tension force on a flexible material, e.g. a rope or cable. In addition, pulleys can be "added together" to create mechanical advantage, by having the flexible material looped over several pulleys in turn. More loops and pulleys increase the mechanical advantage.

# Engineering Ups and Downs



## Student Worksheet: Build Your Elevator

You are a team of engineers who have been given the challenge of building a small elevator system to deliver cars to a three storey toy car garage. Your elevator must be able to securely stop at each floor and lift a toy car of a set weight.

### ◆ Research/Preparation Phase

1. Review the various Student Reference Sheets.

### ◆ Planning as a Team

1. Your team has been provided with some "building materials" by your teacher. You have glue, string, paperclips, paper, pencils, cardboard, cardboard tubes (such as from paper towel or toilet paper rolls), markers, pulleys or thread spools (3), thin rope, string or fishing line, cardboard box to serve as elevator room (shoe box, large milk carton), small toy cars and other resources.
2. Start by meeting with your team and devising a plan to build your elevator. Think about how you will incorporate the pulleys and affix materials to the elevator room which could be a small milk carton, pasta box, or other grocery container.
3. Write or draw your plan in the box below, including your projection for the materials you'll require to complete the construction. Present your design to the class, and explain your choice of materials. You may choose to revise your teams' plan after you receive feedback from class.

Materials Needed:

# Engineering Ups and Downs



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## Student Worksheet: Evaluation

### ◆ Construction Phase

5. Build your elevator!

6. Evaluate your team's results compared to those of other teams, complete the evaluation worksheet, and present your findings to the class.

◆ Use this worksheet to evaluate your team's results in the Engineering Ups and Downs lesson:

1. Did you succeed in creating an elevator that could deliver cars to three stories of the toy car garage? If not, why did it fail?

2. Did you need to request additional or different materials while building your elevator? If so, what happened between the design (drawing) and the actual construction that changed your material needs?

3. Do you think that engineers have to adapt their original plans during the manufacturing process? Why might they?

4. If you had to do it all over again, how would your planned design change? Why?



# Engineering Ups and Downs



## For Teachers: Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the Australian Curriculum in Science

	Year Level			
	7	8	9	10
<b>Science Understandings</b>	Changes to an object's motion is caused by unbalanced forces acting on a object <b>(ACSSU117)</b>			The motion of objects can be described and predicted using the laws of physics <b>(ACSSU229)</b>
<b>Science as a human endeavour</b>	Science knowledge can develop through collaboration and connecting ideas across the disciplines of science <b>(ACSHE223 – Yr 7)</b>		Advances in scientific understandings often rely on developments in technology and technological advances are often linked to scientific discoveries <b>(ACSHE192 – Yr 10)</b>	
<b>Science Inquiry Skills</b>	Summarise data, from student's own investigations and secondary sources, and use scientific understandings to identify relationships and draw conclusions <b>(AC SIS130 – Yr 7)</b>  Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the methods <b>(AC SIS131 – Yr 7)</b>  Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate <b>(AC SIS133 – Yr 7)</b>		Use knowledge of scientific concepts to draw conclusions that are consistent with evidence <b>(AC SIS204 – Yr 10)</b>  Evaluate conclusions and describe specific ways to improve <b>(AC SIS205 – Yr 10)</b>  Communicate scientific ideas and information for a particular purpose <b>(AC SIS208 – Yr 10)</b>	

Mathematics Links with Science Curriculum (Skills used in this activity)	General Capabilities	Cross-Curriculum Priorities
<ul style="list-style-type: none"> <li>Process data using simple tables</li> <li>Data analysis skills (graphs)</li> <li>Analysis of patterns and trends</li> <li>Use of metric units</li> </ul>	<ul style="list-style-type: none"> <li>Literacy</li> <li>Numeracy</li> <li>Critical and creative thinking</li> <li>Personal and social capacity</li> <li>ICT capability</li> </ul>	<ul style="list-style-type: none"> <li>Sustainability</li> </ul>

## Science Achievement Standards

### Year 7

By the end of Year 7, students describe techniques to separate pure substances from mixtures. They **represent and predict the effects of unbalanced forces, including Earth's gravity, on motion**. They explain how the relative positions of the Earth, sun and moon affect phenomena on Earth. They analyse how the sustainable use of resources depends on the way they are formed and cycled through Earth systems. They predict the effect of environmental changes on feeding relationships and classify and organise diverse organisms based on observable differences. **Students describe situations where scientific knowledge from different science disciplines has been used to solve a real-world problem. They explain how the solution was viewed by, and impacted on, different groups in society.**

Students identify questions that can be investigated scientifically. They plan fair experimental methods, identify variables to be changed and measured. They select equipment that improves fairness and accuracy and describe how they considered safety. Students draw on evidence to support their conclusions. They **summarise data from different sources, describe trends and refer to the quality of their data when suggesting improvements to their methods. They communicate their ideas, methods and findings using scientific language and appropriate representations.**

### Year 10

By the end of Year 10, students analyse how the periodic table organises elements and use it to make predictions about the properties of elements. They explain how chemical reactions are used to produce particular products and how different factors influence the rate of reactions. They **explain the concept of energy conservation and represent energy transfer and transformation within systems. They apply relationships between force, mass and acceleration to predict changes in the motions of objects.** Students describe and analyse interactions and cycles within and between Earth's spheres. They evaluate the evidence for scientific theories that explain the origin of the universe and the diversity of life on Earth. They explain the processes that underpin heredity and evolution. Students analyse how the models and theories they use have developed over time and discuss the factors that prompted their view.

Students develop questions and hypotheses and independently design and improve appropriate methods of investigation, including field work and laboratory experimentation. They explain how they have considered reliability, safety, fairness and ethical actions in their methods and identify where digital technologies can be used to enhance the quality of their data. When ***analysing data, selecting evidence and developing and justifying conclusions, they identify alternative explanations for findings and explain any sources of uncertainty***. Students evaluate the validity and reliability of claims made in secondary sources with reference to currently held scientific views, the quality of methodology and the evidence cited. They ***construct evidence-based arguments and select appropriate representations and text types to communicate science ideas for specific purposes***.