Pneumatics
Curriculum Pack

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Introduction

The LEGO® Pneumatics Set from LEGO Education is a great way to teach and learn about the science of compressed air and how it relates to the real world.

Who is it for?

The LEGO Pneumatics Set is designed for use in middle school and junior high school classrooms. Focusing on grades six through eight, the pneumatics curriculum can easily be adapted and used at the high school level as well.

Teacher materials provide step-by-step guidance to effectively relate pneumatic principles to students through a variety of hands-on activities and class-lead discussions. Student materials use instruction, investigative questioning, and helpful hints to ensure progress and provide scientific understanding. Both you and your students will be successfully guided through the curriculum as you explore the world of pneumatics.

What is it for?

LEGO Education science and technology solutions enable students to behave as technical investigators by providing them with tools and tasks that promote scientific inquiry. By using LEGO solutions, students are encouraged to pose 'What if...?' questions. They make predictions (hypotheses), test behaviors of models, and record and present findings.

The 'Pneumatics' curriculum pack presents scientific and technical concepts in a motivating and exciting way that will encourage creativity and teamwork among students. These activities allow for the integration of a wide range of science, design, technology, and mathematical concepts, thus supporting a highly efficient learning experience. These activities also enable teachers to partially cover the following Crosscutting Concepts and overall Science and Engineering Practices, which have been set forth in the Next Generation Science Standards (NGSS).

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

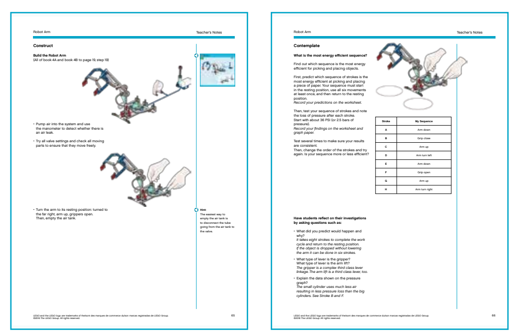
Crosscutting Concepts:
• Patterns
• Cause and Effect (Mechanism and explanation)
• Scale, Proportion, and Quantity
• Systems and System Models
• Energy and Matter (Flows, cycles, and conservation)
• Structure and Function
• Stability and Change

What is in it?

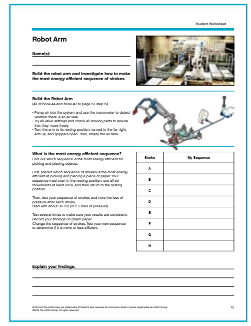
The set consists of 31 elements including pumps, cylinders, and valves – many of which are unique to this product. All of the elements and the building instruction booklets fit into the bottom section of the storage box.
The activity pack consists of 14 principle model activities, four main activities, and two designing and making activities.
The set is both easy to use and easy to manage within a classroom setting, providing the ideal tool for effective hands-on learning!

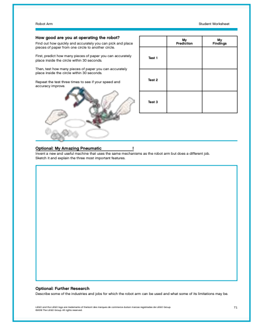
Building Instructions Booklets
Unique to LEGO® Education science and technology solutions is the Buddy Building instruction booklet. Combining teamwork with learning, these booklets are designed for groups of two students. Each buddy (student) is provided a booklet (A or B) and is required to build only half of the model. After each buddy completes his or her portion of the assembly, the two work as a team to construct the final, more sophisticated and powerful model.

Teacher's Notes
In the Teacher's Notes, you will find activities as well as questions, answers, hints and ideas for further investigations.
Every activity is carefully linked to the overall objectives of the science, and design & technology curriculum. At the start of each activity, we list the outcomes unique to that particular activity. The outcomes that are common to all activities are listed in the section called 'What are the curriculum highlights?'. We also list the specific vocabulary focus and the additional
materials needed for each activity.



Student Worksheets
The student worksheets guide the students through the investigations without requiring too much assistance from you. They will predict, test, take measurements and record data, and change the models to compare and contrast findings, and finally draw conclusions.





You can ask the students to compare their worksheets and share their findings with each other for a greater understanding of the concepts they have just explored. You could also use the students' findings as an opportunity to discuss concepts, such as fair testing and variables.

At the end of each activity, the students are challenged to invent and sketch a device that applies the major concepts they have just explored. This is ideal as an extra challenge or homework project.

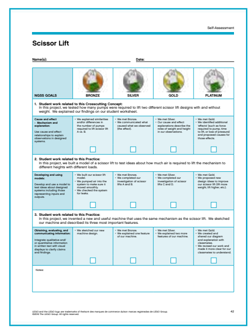
Assessments

Assessment materials are provided for all four of the activities and the six problem-solving activities.

What learning goals are assessed?

- **Activity Assessment**

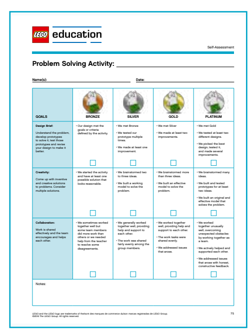
Practices of Scientists & Engineers and Crosscutting Concepts: A rubric page on which students can evaluate their activity work according to learning goals based on two NGSS Practices and one theme from the NGSS Crosscutting Concepts.



- **Problem-Solving Assessment**

Evaluate Design, Creativity, and Collaboration: A rubric page on which students can evaluate their problem-solving work according to the engineering-related learning goals from the NGSS and a set of learning goals that are prominent in both the Common Core State Standards and 21st century skill set, specifically:

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



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

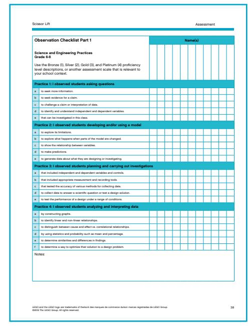
Students should mark the rubric. If you prefer to emphasize formative assessment, ask the students to record dates in the rubric that correspond to their completion of each level.

You can also use the rubrics for your own evaluation of the students' work, marking in the appropriate column, and writing optional comments in the 'Notes' column.

- **Observation Checklist**

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

You can use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or use one that is relevant to your school context.

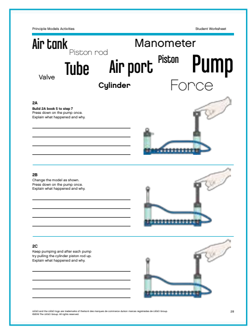


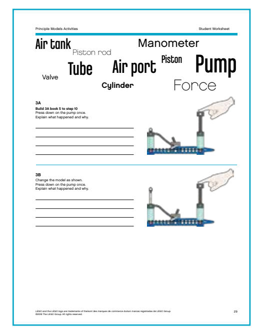
Where can I find the assessment materials?
You can find the assessment materials in the Teacher's Notes for each activity and problem-solving activity.

Three Levels of Progression

The "Advancing with Simple & Powered Machines" curriculum pack consists of fourteen principle models, six activities, and two designing and making activities. Each of these three components represents one level of progression, and each of these is described in more detail below.

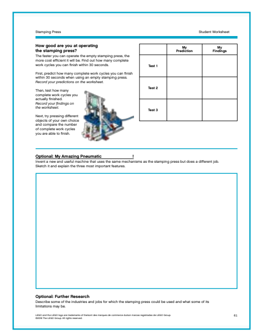
Principle Models
The principle models introduce students to the basic concepts of pneumatics and provide an opportunity to gain an understanding of pneumatics. Students experiment with easy-to-build models using progressive building instructions and activities. Each principle model comes with a student worksheet that presents a selection of words that will encourage students to use the correct terminology associated with pneumatics, both in their investigations and explanations.





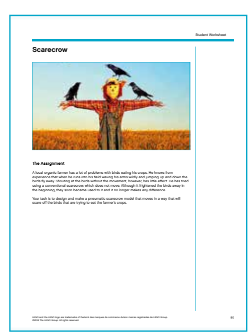
Activities
The six activities allow students to apply and develop their knowledge of science and engineering design. These activities create a positive learning environment and offer a complete scientific learning process in which the students are able to make predictions, build models, run tests, record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

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



Designing and Making Activities
The goal of these activities is for students to design their own solutions to various real life needs. Students learn to design and create a solution, evaluate the process used, and communicate the focus used to meet the design criteria. Each activity builds on the knowledge, skills, and understanding gained from both the principle and main activities.

The Teacher's Notes for each designing and making activity provide advice on how to evaluate the proposed solution. A picture of a model solution is provided. You may use this to help students who get stuck in the design process. Note that it is not the one and only solution. You should always encourage students to design their own solutions.



The LEGO® Pneumatics Set provides students with the opportunity to obtain an in-depth understanding of pneumatics through hands-on activities.

The sections 'What is pneumatics?' and 'principle models' will guide you and your students through the basics of pneumatics. The four main activities let students explore pneumatic concepts at work and two designing and making activities that deal with pneumatics. Also included is a curriculum section that pinpoints the key learning concepts covered,

What is pneumatics?
This section presents the basics of pneumatics: what it is, how it works, and how it is used. The section also features a guide to the design and function of each of the elements, and includes four pages you can print and display in your classroom. You may choose to use this section as part of your own preparation and/or give it to your students.

Classroom Management Tips For Your First LEGO® Education Activity, and Beyond

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

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

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

How do I handle the building instructions booklets?
For easy classroom management we suggest storing the building instructions booklets in binders so that they are close-at-hand and ready to use at the beginning of each lesson.

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

How much time is needed?
Students should be able to do all of the principle activities within two 45-minute class periods.

When working with each of the main activities, most students will be able to build, test, explore, and put away the parts within 45 minutes. A double period is ideal for more in-depth investigations of the key learning areas.

For the designing and making activities, students may need more time to build and explain their models.

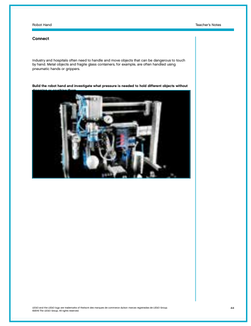
What is needed in my classroom?
Tables may be pushed aside to allow models to roll across a smooth floor. Ideally, a computer or computers should be available so that students can explore the activity videos.

Students need to be able to construct in pairs facing each other or side-by-side. From teachers and classrooms we have learned that cafeteria-type trays are ideal to build on, and to stop elements rolling onto the floor. It is also an advantage to have a cupboard or shelves to store the sets lying flat with any unfinished models on top of them.

LEGO® Education 4C Approach

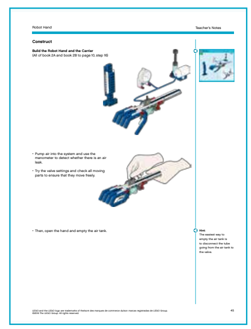
The lessons follow LEGO® Education's 4C approach; Connect, Construct, Contemplate, and Continue. This enables you to progress naturally through the activities.

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

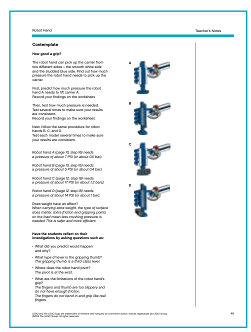


We suggest using the text and photograph as a starting point for a class discussion or draw on your own experiences to provide an engaging introduction to the activity. Please also consider involving current events related to the topic, both near and far, to set the scene for the students.

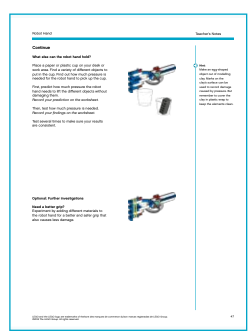
Construct
The construction of models engages both hands and minds. Using the building instructions, students build models embodying the concepts related to the key learning areas. Tips are provided for testing and ensuring each model functions as intended.



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



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



Pneumatic Learning Grid

Objective Number	NGSS Grade 6-8 ● = Fully covered ◐ = Partially covered	Activities				Designing and Making	
		Scissor Lift	Robot Hand	Stamping Press	Robot Arm	Dinosaur	Scarecrow
Disciplinary Core Ideas: Physical Science							
1	MS-PS2 Motion and Stability: Forces and Interactions	◐	◐	◐	◐	◐	◐
2	MS-PS3 Energy	◐	●	◐	◐	◐	◐
Crosscutting Concepts							
1	Patterns	◐	◐	◐	●	◐	◐
2	Cause and effect: Mechanism and explanation	●	●	●	●	●	●
3	Scale, proportion, and quantity	◐	◐	◐	◐	◐	◐
4	Systems and system models	●	●	●	●	●	●
5	Energy and matter: Flows, cycles, and conservation	◐	◐	◐	◐	◐	◐
6	Structure and Function	●	●	●	●	●	●
7	Stability and change	●	●	●	●	●	●
Science and Engineering Practices							
1	Asking questions and Defining Problems	●	●	●	●	●	●
2	Developing and using models	●	●	●	●	●	●
3	Planning and carrying out investigations	●	●	●	●	●	●
4	Analyzing and interpreting data	●	●	●	●	●	●
5	Using mathematics, Informational and Computer Technology, and computational thinking	◐	◐	◐	●	●	●
6	Constructing explanations and designing solutions	●	●	●	●	●	●
7	Engaging in argument from evidence	◐	◐	◐	●	●	●
8	Obtaining, evaluating, and communicating information	●	●	●	●	●	●

Objective Number	Common Core State Standards Grade 6-8 ● = Fully covered ◐ = Partially covered	Activities: Scissor Lift	Activities: Robot Hand	Activities: Stamping Press	Activities: Robot Arm	Designing and Making: Dinosaur	Designing and Making: Scarecrow
Mathematical Practice							
MP1	Make sense of problems and persevere in solving them	◐	◐	◐	◐	◐	◐
MP2	Reason abstractly and quantitatively	◐	◐	◐	◐	◐	◐
MP3	Construct viable arguments and critique the reasoning of others	◐	◐	◐	◐	◐	◐
MP4	Model with mathematics	●	●	●	●	●	●
MP5	Use appropriate tools strategically	●	●	●	●	●	●
MP6	Attend to precision	◐	◐	◐	◐	◐	◐
MP7	Look for and make use of structure	◐	◐	◐	◐	◐	◐
MP8	Look for and express regularity in repeated reasoning	◐	◐	◐	◐	◐	◐
Ratios & Proportional Relationships							
7.RP.A	Analyze proportional relationships and use them to solve real-world and mathematical problems	◐	◐	◐	◐		
Speaking and Listening							
SL 6-8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly	●	●	●	●	◐	◐
SL 6-8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation	◐	◐	◐	◐	◐	◐
Reading Standards for Literacy in Science and Technical							
RST 6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks	●	●	●	●		
RST 6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics	●	●	●	●		
RST 6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table)	●	●	●	●	●	●
Writing Standards for Literacy in History/Social Studies, Science & Technical Subjects							
WHST. 6-8.1	Write arguments focused on discipline-specific content	●	●	●	●		
WHST. 6-8.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes	●	●	●	●		
WHST. 6-8.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience	●	●	●	●		
WHST. 6-8.5	With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed	◐	◐	◐	◐		
WHST. 6-8.6	Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently	◐	◐	◐	◐		
WHST. 6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration	●	●	●	●		

What is pneumatics?

What does pneumatic mean?

The term 'pneumatic' is based on the Greek word 'pneumatikos', meaning 'coming from the wind.' Pneumatic is defined as the use of pressurized air to do work. Pneumatic machines have been used for many years. In fact, 2,000 years ago a famous Greek inventor, Hero of Alexandria made a large variety of pneumatic machines, including a pneumatic catapult.

Why use pneumatics?

If you have ever been to the dentist and had your teeth drilled or polished, you may have had a close encounter with a pneumatic machine without even knowing it! Pneumatic dental instruments are often the preferred choice of dentists because of the instruments' high momentum and smooth operation.

Some of the benefits of using pneumatic systems are:

- Pneumatic machines can be very small, light, fast, and powerful.
- Air is light and free compared to hydraulic fluid.
- You can very easily store compressed air.
- Pneumatic machines are safe even when their air hoses or individual parts get wet.
- If a pneumatic machine is overloaded, the machine will stop, continue compressing, or release the air through a pressure release valve.

Some of the dangers of pneumatic systems are:

- If there is a hose leak in hydraulic machines, fluid can cause the surrounding area to become slippery and dangerous.
- Note that any fluid, even air, under high pressure can potentially be dangerous!

How does it work?

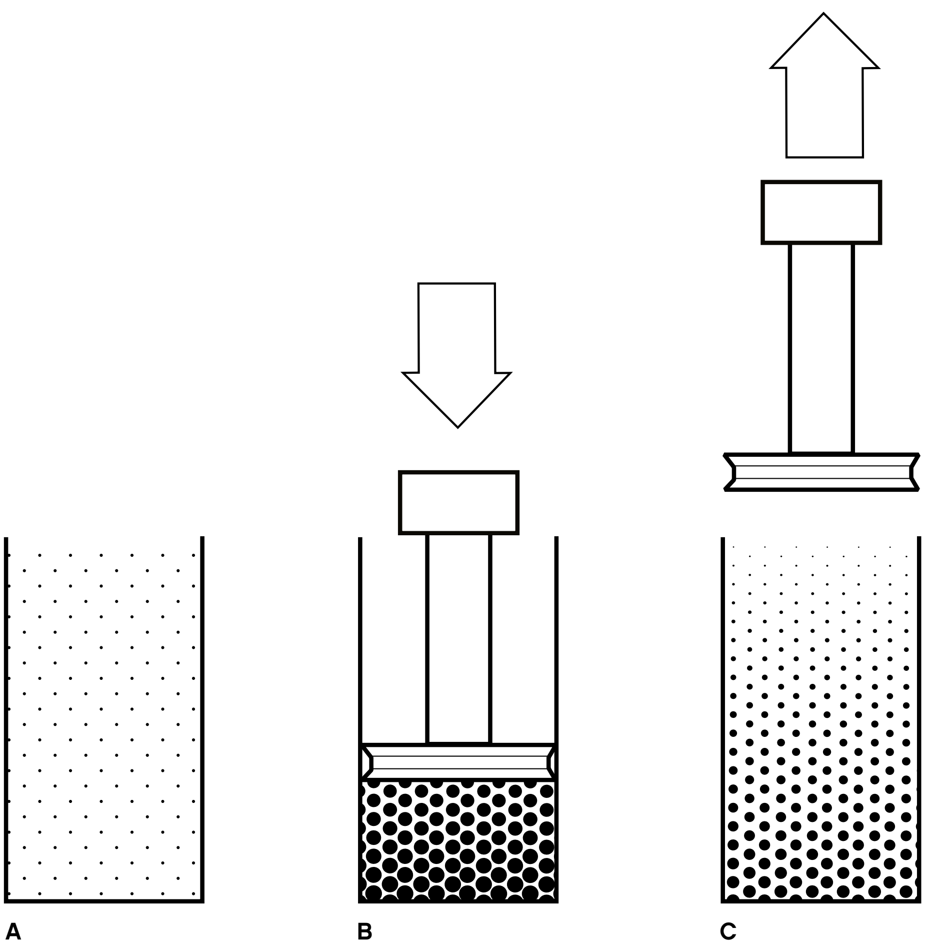
Consider an empty container, such as container A. Even though it may look empty, it is actually full of air molecules. Air molecules are invisible, but they still possess weight and mass, and exert pressure. container A's pressure matches the air pressure of the room it is in.

Once the container is sealed (container B) the molecules trapped inside exert pressure when squeezed or 'compressed' as they collide with each other and the sides of the container. It is the empty space and the elasticity of the impact between the air molecules and the container that allows for the air to be compressed. The force of the air molecules acting on a surface, such as the piston, is called pressure.

The amount of pressure the air molecules exert depends on the number of molecules and amount of collisions that occur between the molecules and the inside surface of the container. Air molecules that are compressed contain potential energy.
If the hand and piston are removed (container C), the compressed air will expand until the pressure inside and outside the container are the same.
Using a controlled airflow circuit, the force of expanding air can be converted into kinetic energy that can power and operate a system.

Hint:
For explanations of specific words, turn to the glossary.

Did you know?
If you want to know more about how to calculate pressure, we suggest you start with Boyle's Law.



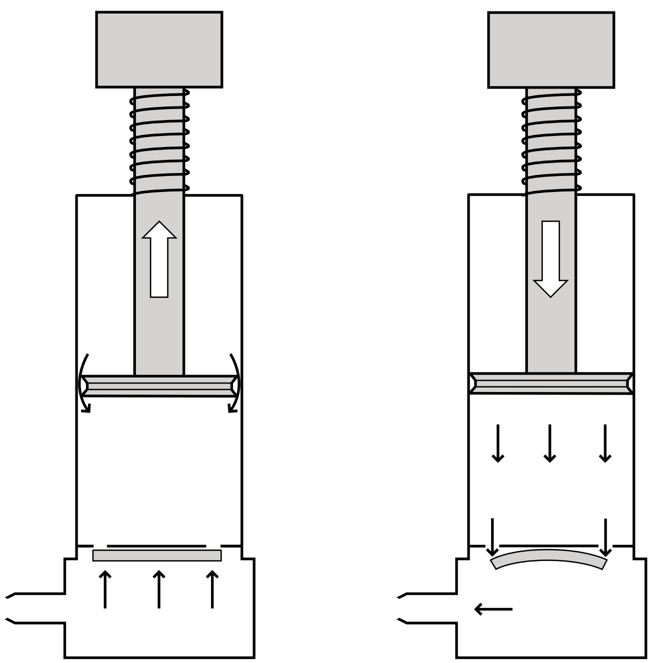
Inside the LEGO® Pneumatic Elements

Pumps, cylinders, and valves are the basic components of any pneumatic system. Even though industry uses a much larger variety of components, most operations can be performed with just these three basic components.

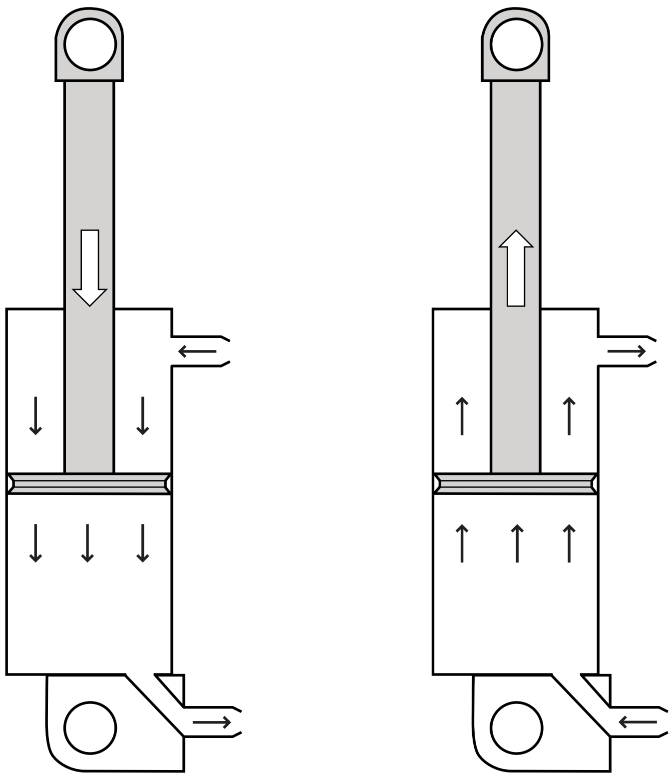
The Pump
The pump is used to compress air. To control the airflow inside the pump a specially designed piston and a flexible diaphragm are used.

On the down stroke, the seal of the pump's piston becomes airtight. The compressed air bends the flexible diaphragm allowing air to flow through to the outlet port.

On the return stroke the piston seal allows air to flow past the piston and back into the barrel of the pump. At the same time, the flexible diaphragm snaps back into place and stops any compressed air from flowing back into the pump barrel.



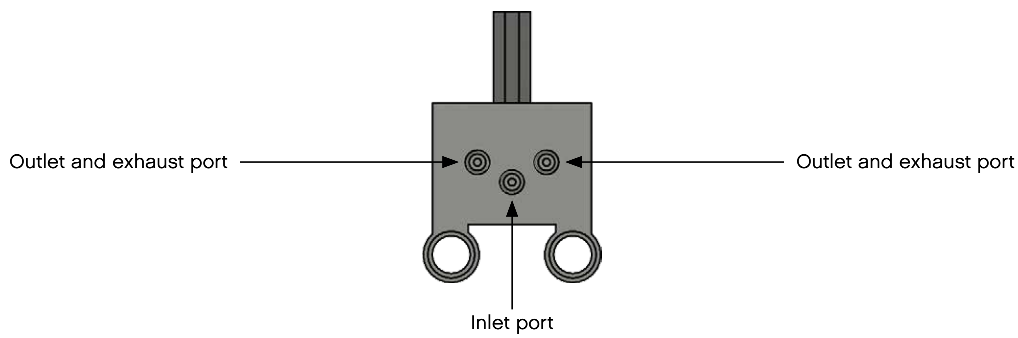
The Cylinder
The pneumatic cylinder works by converting the force of expanding air (potential energy) into movement (kinetic energy). When air enters the cylinder, the force of the expanding air will either force the piston up or down, depending on which air port the air has entered from. All LEGO® cylinders are double-acting cylinders, meaning compressed air can enter the cylinder through two air ports.



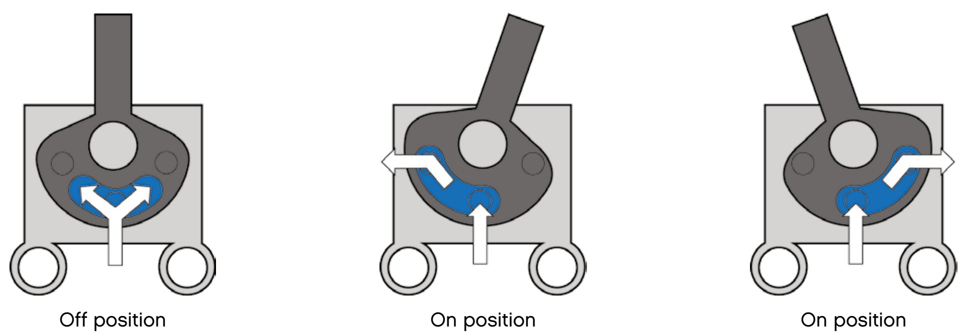
Did you know?
The smaller the cylinder the greater the pressure it needs to operate. This is due to the smaller area of the piston. Pressure is force divided by area. As the area gets smaller, dividing the force by the area leads to a greater value for the pressure.

pressure = force ÷ area

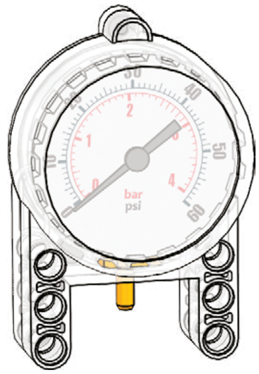
The Three-Position Valve
The valve receives compressed air from the pump or tank through the inlet port. The valve directs the airflow through one of the two outlet ports to other pneumatic elements or simply stops the airflow. The rubber valve seal has a specially designed chamber to direct air from the inlet port to one of the two outlet ports.
The outlet port that is not being used for compressed air is automatically opened, allowing air from a cylinder to escape.



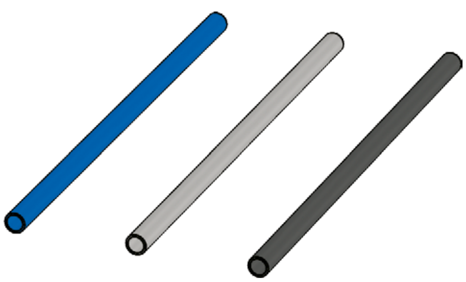
Valves Controlling the Direction of the Compressed Air



The Manometer
A manometer is an instrument for measuring pressure. Using the manometer allows you to follow the rise or drop in air pressure created by your actions. The LEGO® manometer gives you a pressure reading in both bar and psi (pounds per square inch).



Tubes, T-pieces, and Air Tank
The flexible tubes, which come in different lengths and colors, are used to transport the compressed air between the pneumatic elements. The colors help you find errors, and trace and describe the airflow. The tubes are specially designed to leak air at the connections if the pressure becomes too high.
T-pieces allow air to flow to several tubes at the same time.
The air tank is used for storing air under pressure.

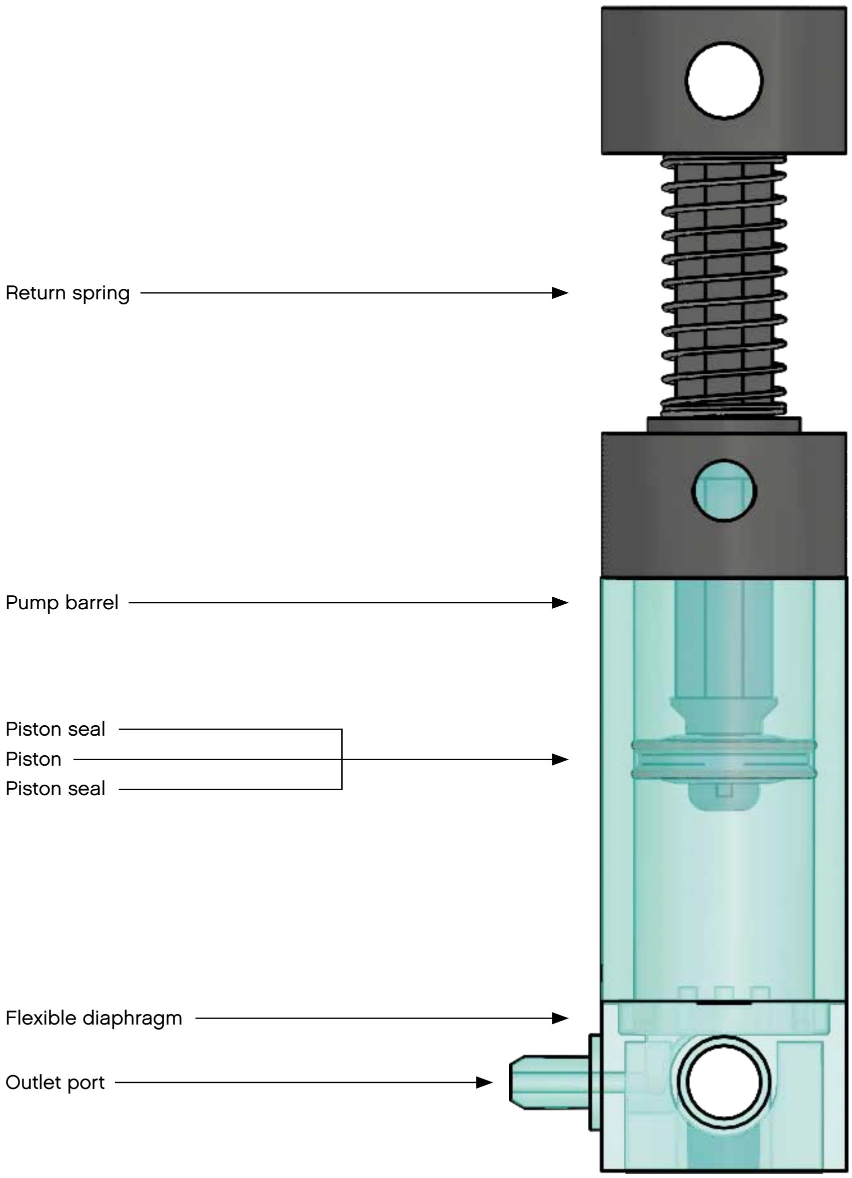

Tubes


Air tank

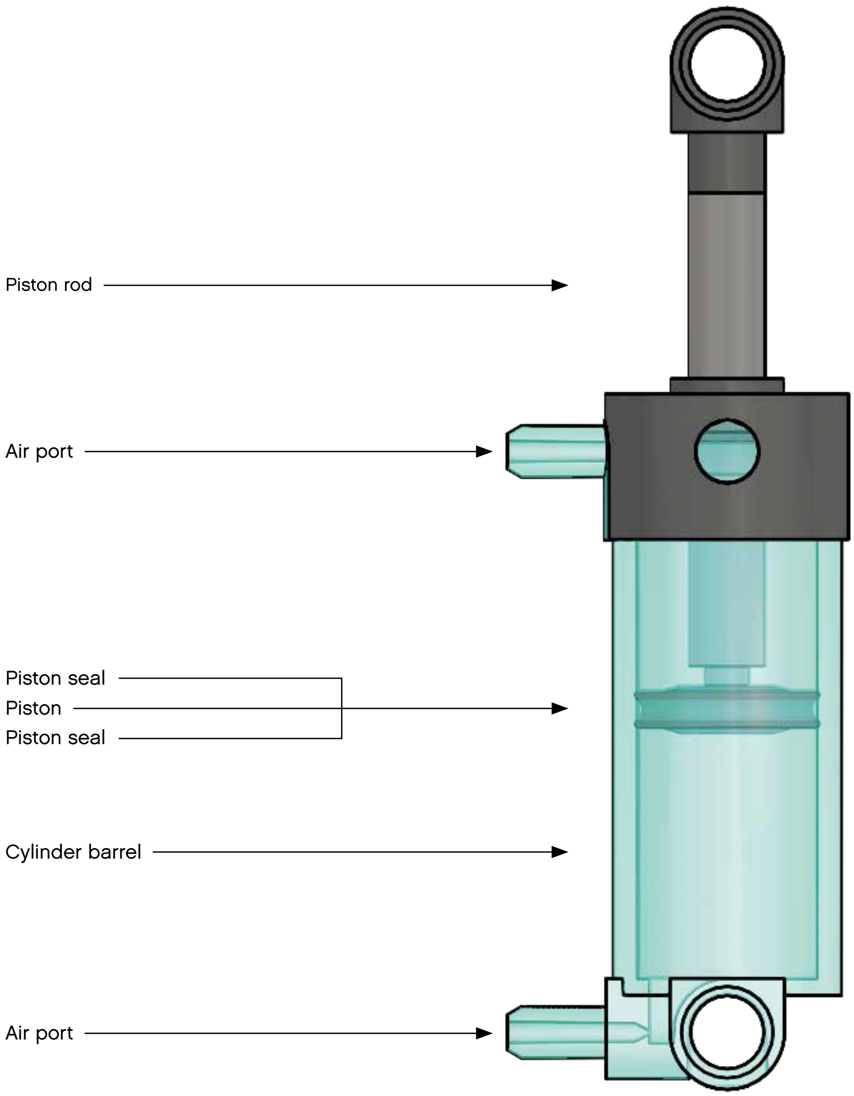

T-piece

Hint:
The LEGO models use tubing according to the following rules:
Blue tubes are used to transport air between the pump, air tank, and valve.
Light grey tubes are used to transport air between the valve and bottom cylinder air port.
Black tubes are used to transport air between the valve and top cylinder air port.

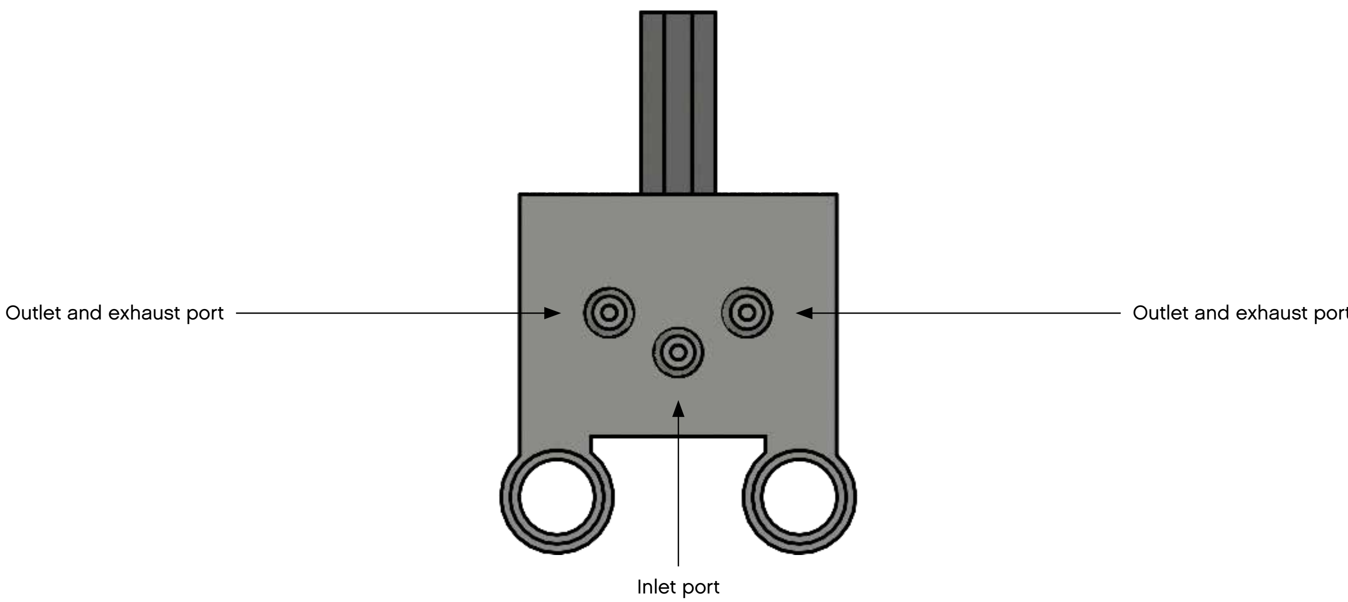
The Pump

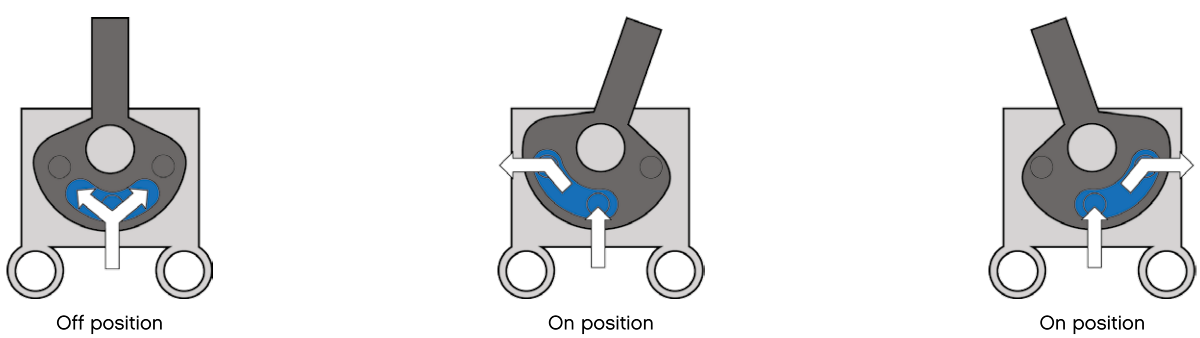

Return spring
Pump barrel
Piston seal
Piston
Piston seal
Flexible diaphragm
Outlet port

The Cylinder



The Three-Position Valve





Principle Models

A Quick Guide to the Components and the Principles of Pneumatics
The principle model building instruction booklet is full of small, quick-to-build, and easily changeable models. The principle model activities provide an insight into how pneumatic components work. They can be used to gain a greater understanding of the more complex main activities as well as the designing and making activities.

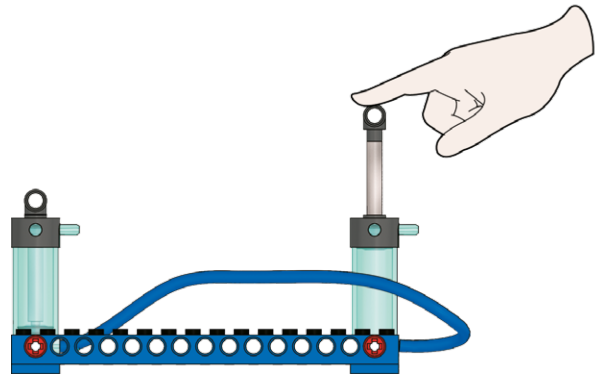
Who are they for?
They are designed for students! Through the natural progression of activities, students experience the magic of pneumatics. They explore, understand, and feel first-hand how pneumatics works. Student worksheets guide students through the investigations and basic principles of pneumatics, enabling them to document their findings.

When can I use the models?
Use the activities when you introduce pneumatics to your students. By using these models students will become familiar with the construction techniques and terminology associated with pneumatics. The experience students gain from the principle model activities can be used as a point of reference when they begin working with the main activities and the designing and making activities.

1A

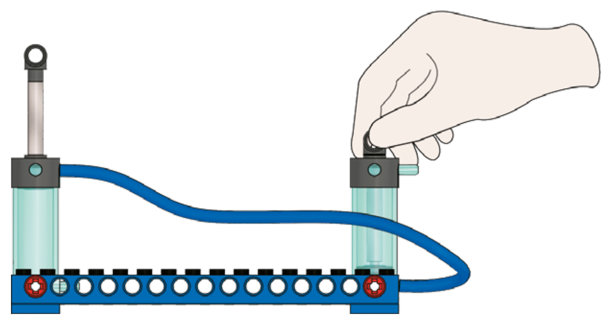
Build 1A book 5 to step 5

As you press down on the piston rod, the piston will force the air out of the bottom air port, into the tube, and then into the bottom air port of the second cylinder. The force of the expanding air will force the piston of the second cylinder to move up, thereby extending the piston rod.



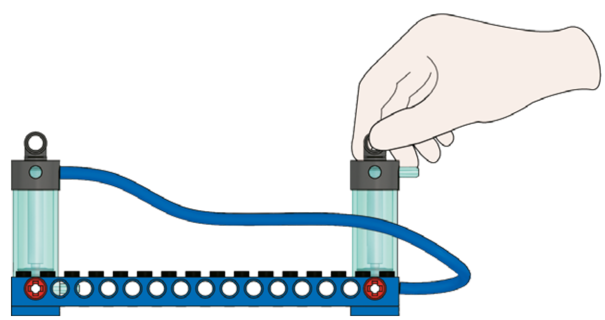
1B

As you pull up on the piston rod, you create a vacuum inside the cylinder and tube. As you let go, the force of the pressure returning to its initial state forces the piston and piston rod down again.



1C

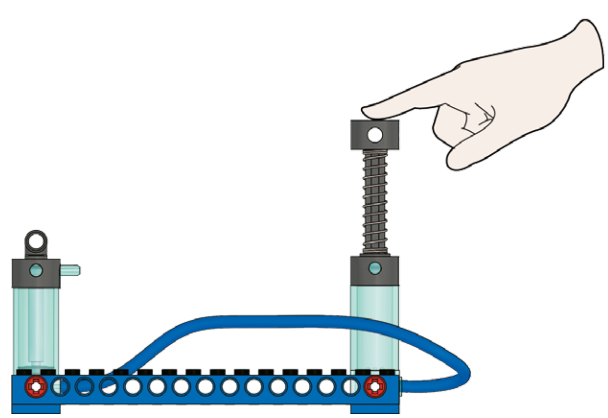
As you pull up on the piston rod, you draw air from the second cylinder and tube into the first cylinder. The first cylinder's piston rod will remain extended after you let go of it. The vacuum created by the force of the air flowing from the second to the first cylinder forces the second cylinder's piston up, thereby extending the second cylinder's piston rod.



2A

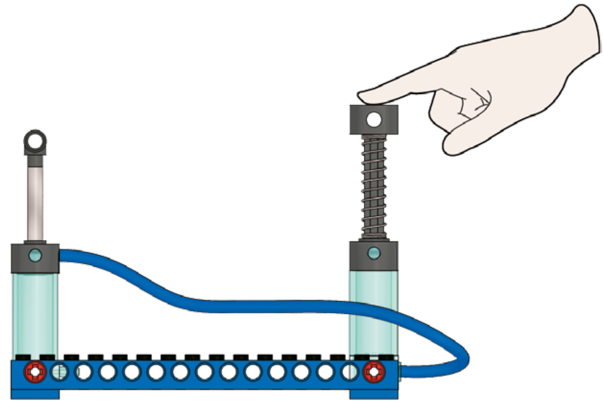
Build 2A book 5 to step 7

The pump forces the air into the tube and into the cylinder's bottom air port. This forces the piston up and the piston rod will extend almost completely.



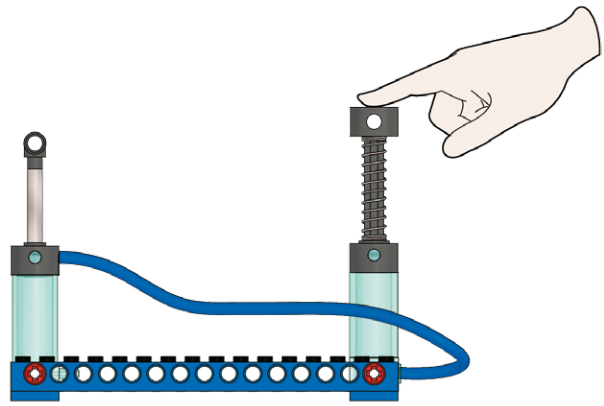
2B

The pump forces the air into the tube and into the cylinder's top air port. This forces the piston down and the piston rod will completely retract.



2C

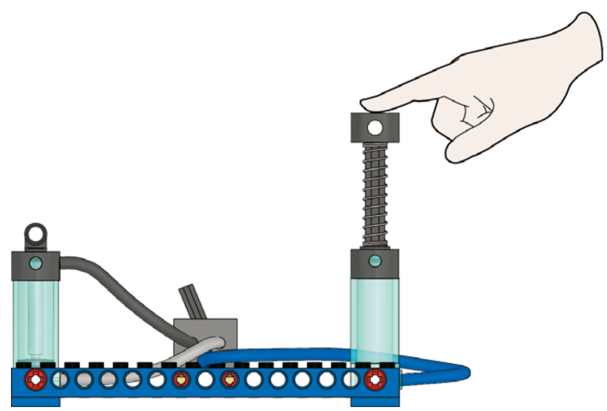
After one pump you will be able to completely extend the piston rod. After two pumps it becomes much harder. After four pumps it is very difficult to extend to piston rod. And after six pumps the pump or tube will begin leaking air.



3A

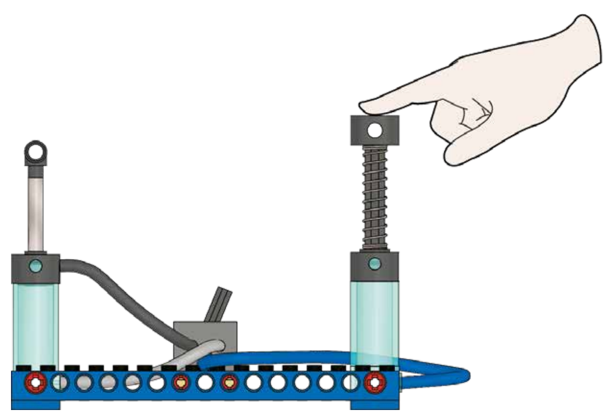
Build 3A book 5 to step 10

As you press down on the pump, the air will flow from the pump into the valve, directing the air into the tube that leads to the cylinder's bottom air port. As the air enters the cylinder it forces the piston up, thereby extending the piston rod.



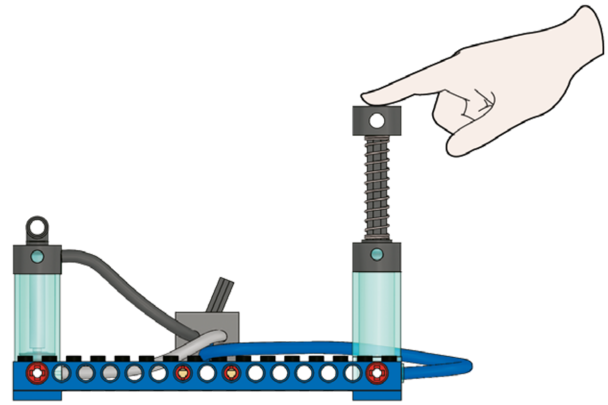
3B

As you press down on the pump, the air will flow from the pump into the valve, directing the air into the tube that leads to the cylinder's top air port. As the air enters the cylinder it forces the piston down, thereby retracting the piston rod.



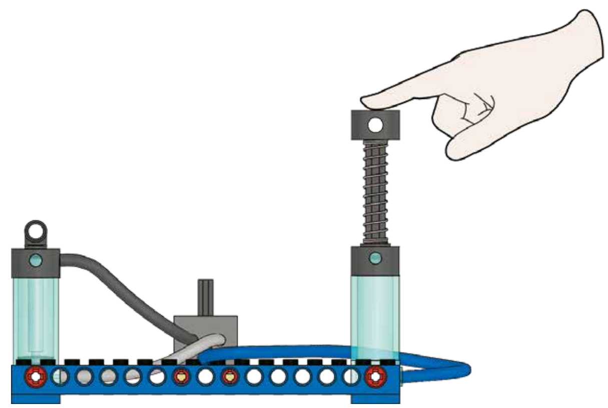
3C

As you press down on the pump, the air will flow from the pump into the valve, directing the air into the tube that leads to the cylinder's top air port. As the air enters the cylinder it forces the piston down, but as the piston is already down, nothing happens. After about seven pumps, the pump or tube will begin leaking air.



3D

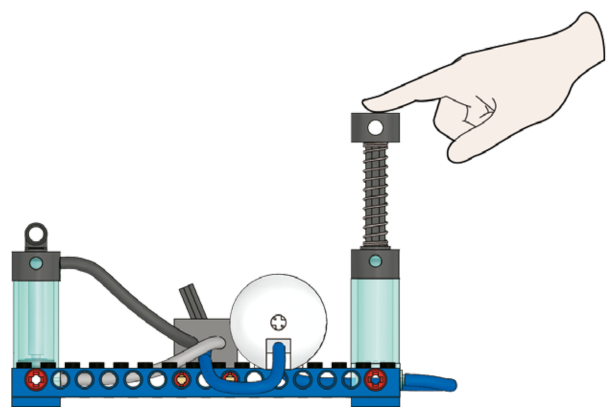
As you press down on the pump, the air will flow from the pump to the valve, where it is stopped. After about two pumps, the pump or tube will begin leaking air.



4A

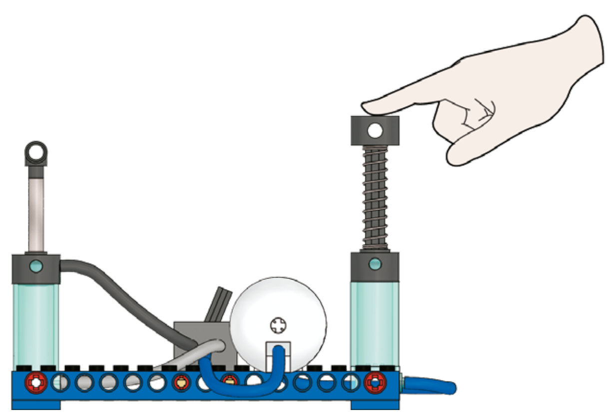
Build 4A book 5 to step 13

As you press down on the pump, the air will flow from the pump, through the air tank and into the valve, directing the air into the tube that leads to the cylinder's bottom air port. As the air enters the cylinder it forces the piston up, thereby extending the piston rod. After two pumps the piston rod will be fully extended.



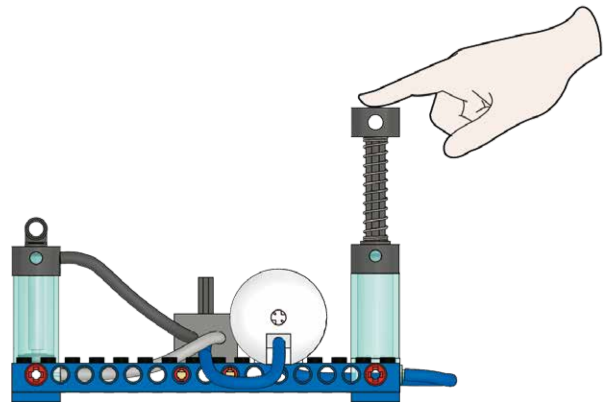
4B

As you press down on the pump, the air will flow from the pump, through the air tank and into the valve, directing the air into the tube that leads to the cylinder's top air port. As the air enters the cylinder it forces the piston down, thereby retracting the piston rod. After two pumps the piston rod will be fully retracted.



4C

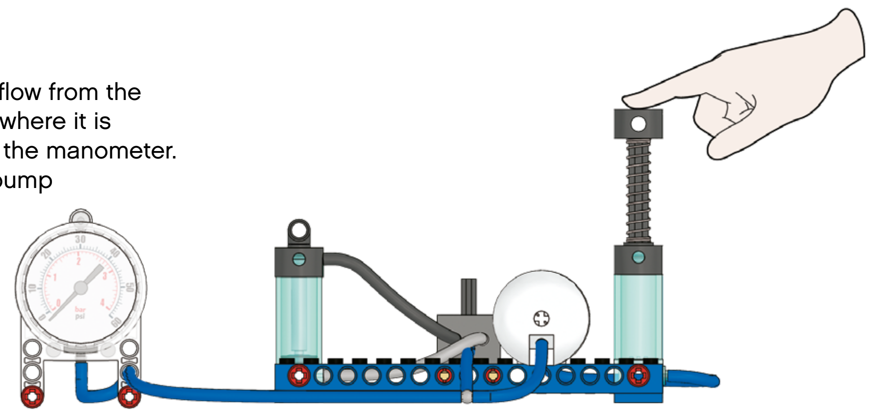
As you press down on the pump, the air will flow from the pump, through the air tank and to the valve, where it is stopped. After about 40 pumps the pump or tube will begin leaking air.



5A

Build 5A book 5 to step 17

As you press down on the pump, the air will flow from the pump, through the air tank and to the valve, where it is stopped. The pressure can be monitored on the manometer. At a pressure of about 43 PSI or 3 bars the pump or tube will begin leaking air.



You can get six complete cylinder actions from about 14 PSI or 1 bar.

You can get 11 complete cylinder actions from about 29 PSI (or 2 bars).

You can get 13 complete cylinder actions from about 36 PSI (or 2.5 bars).

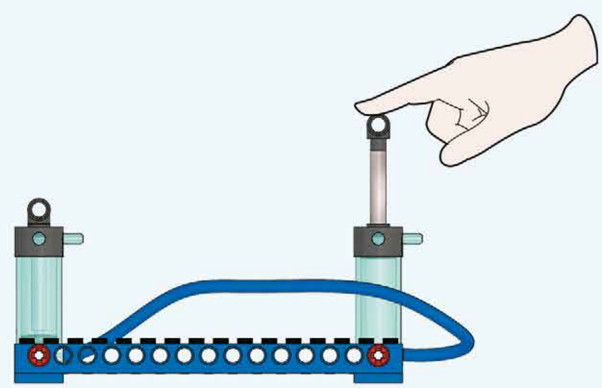
Principle Models Activities

The principle models show you how pneumatics works in a simple and hands-on way. Use the Buddy Building instruction booklets to build each model. Investigate using the models, and then explain your observations. You may use the words presented at the top of each page as you write your findings. (Do you need to repeat the same words at the top of each page or just create a vocabulary page for students to use as a reference?)
Next, make a minor change as shown in the illustration. Continue your investigations. There are 14 steps used to create five principle models. When you have completed these steps, you will be ready to make interesting pneumatic machines.

Air tank Piston rod Manometer Tube Air port Piston Pump Valve Cylinder Force

1A
Build 1A book 5 to step 5.
Press down on the piston rod.
Explain what happened and why.

When I push down on the piston rod...

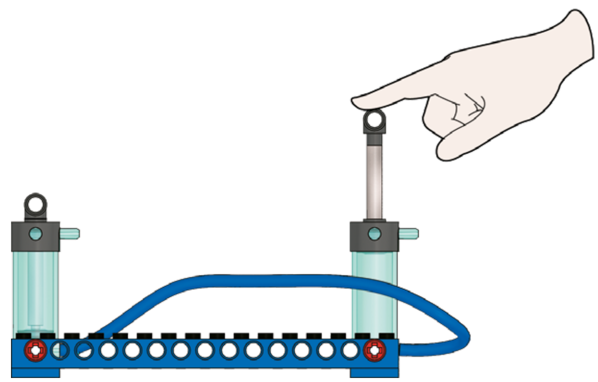


Hints:
- The easiest way to empty the air tank is to disconnect the tube going from the air tank to the valve.
- It is always a good idea to start with the valve in the off position. This allows you to control the airflow.

Air tank
Manometer
Piston rod
Piston
Pump
Tube
Air port
Valve
Cylinder
Force

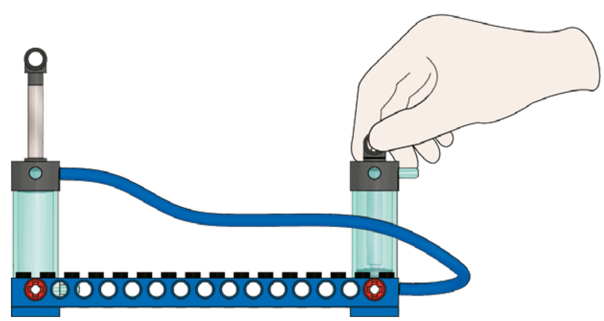
1A

Build 1A book 5 to step 5
Press down on the piston rod.
Explain what happened and why.



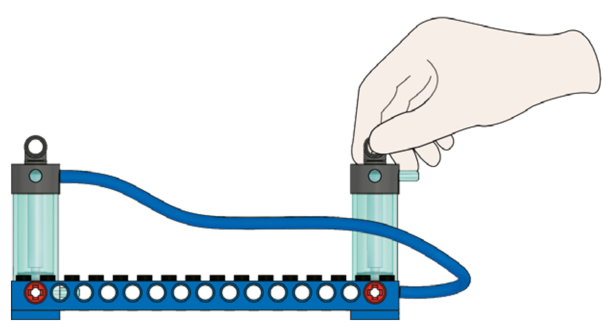
1B

Change the model as shown.
Pull up on the piston rod.
Explain what happened and why.



1C

Change the model as shown.
Pull up on the piston rod.
Explain what happened and why.



Air tank Piston rod Manometer

Piston Pump

Valve Tube Air port

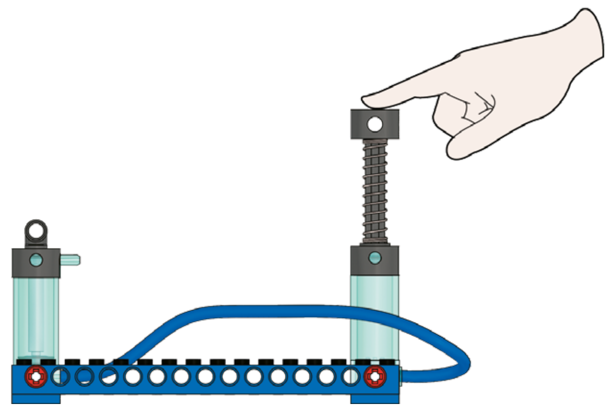
Cylinder Force

2A

Build 2A book 5 to step 7

Press down on the pump once.

Explain what happened and why.

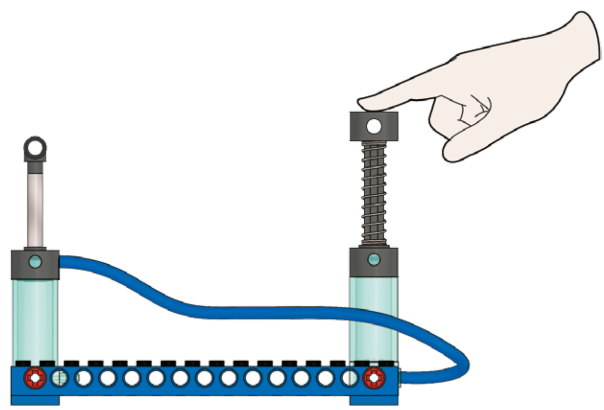


2B

Change the model as shown.

Press down on the pump once.

Explain what happened and why.

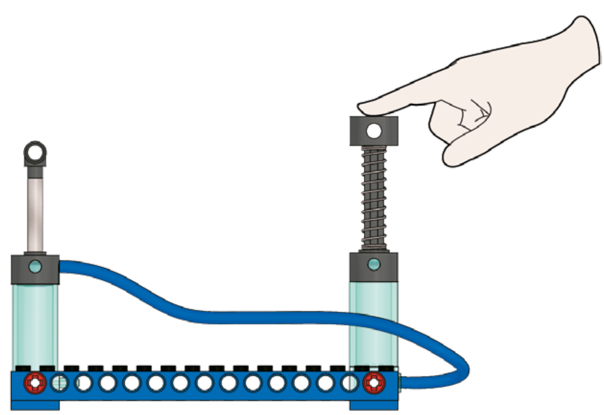


2C

Keep pumping and after each pump

try pulling the cylinder piston rod up.

Explain what happened and why.



Air tank

Piston rod

Manometer

Piston

Pump

Tube

Air port

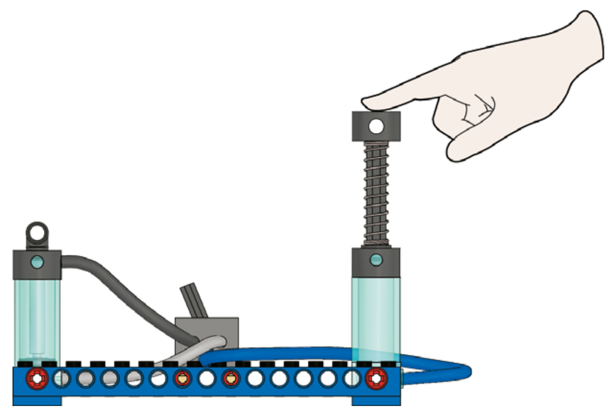
Valve

Cylinder

Force

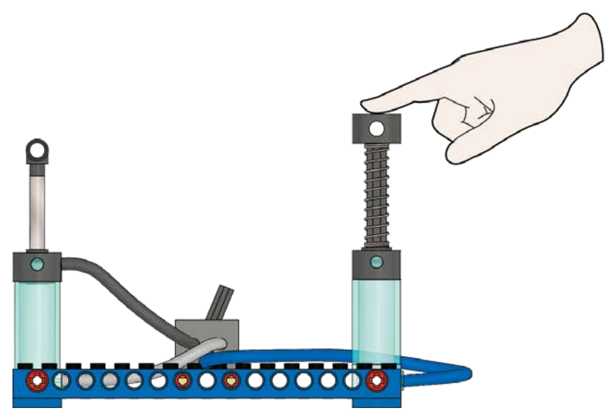
3A

Build 3A book 5 to step 10
Press down on the pump once.
Explain what happened and why.



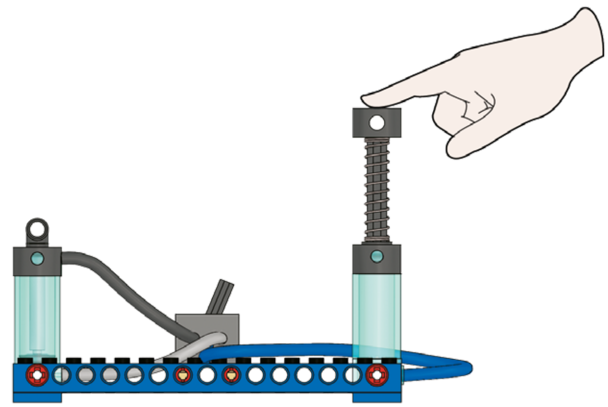
3B

Change the model as shown.
Press down on the pump once.
Explain what happened and why.

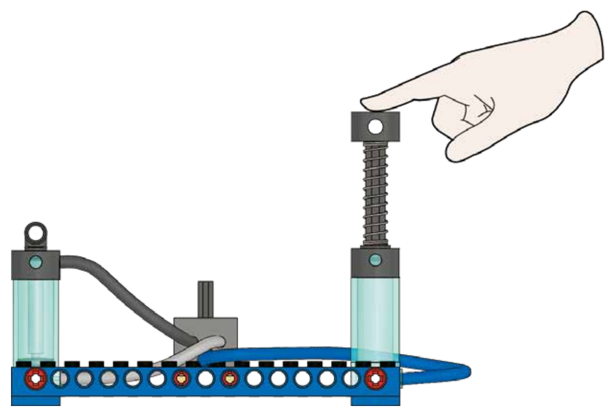


Air tank
Piston rod
Manometer
Piston
Pump
Tube
Air port
Valve
Cylinder
Force

3C
Change the model as shown.
Press down on the pump once.
Explain what happened and why.



3D
Change the model as shown.
Press down on the pump twice.
Explain what happened and why.



Air tank

Manometer

Piston rod

Piston

Tube

Air port

Pump

Valve

Cylinder

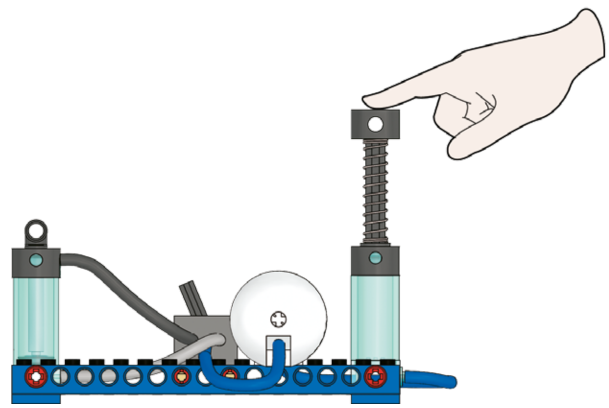
Force

4A

Build 4A book 5 to step 13

Press down on the pump twice.

Explain what happened and why.

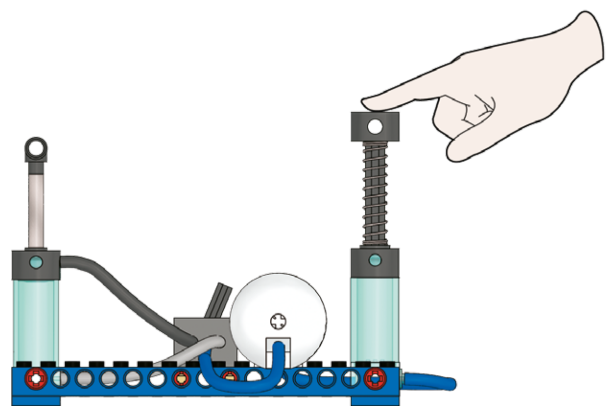


4B

Change the model as shown.

Press down on the pump twice.

Explain what happened and why.



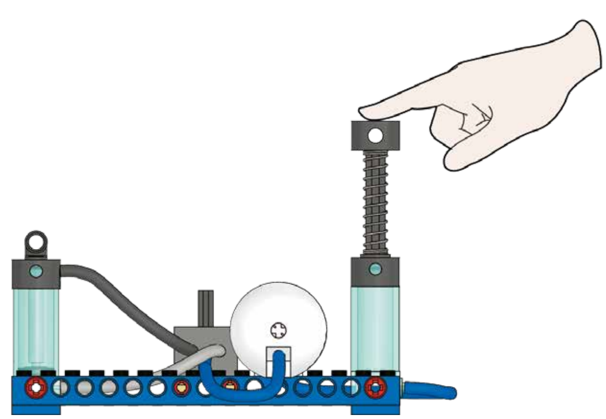
4C

Change the model as shown.

Press down on the pump twice.

Explain what happened and why.

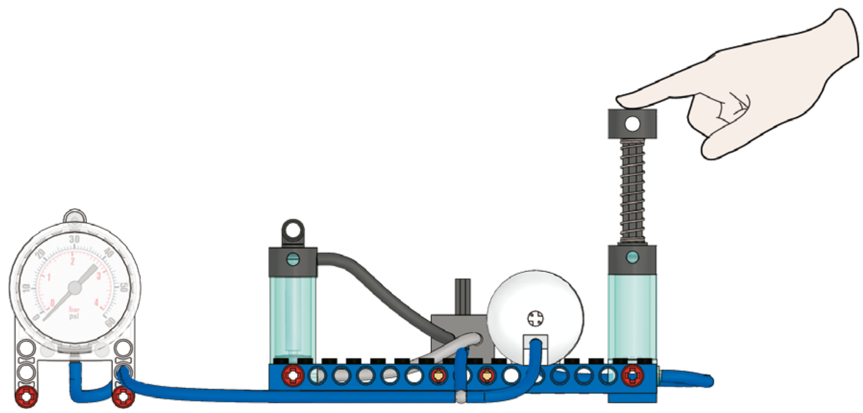
How many pumps are needed to fill the tank completely?



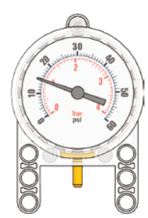
Air tank
Manometer
Piston rod
Piston
Tube
Air port
Pump
Valve
Cylinder
Force

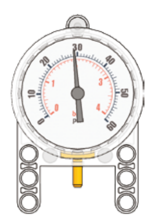
5A

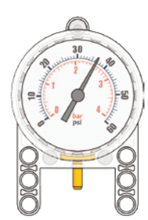
Build 5A book 5 to step 17
Press down on the pump twice.
Explain what happened and why.
Keep pumping.
What's the highest pressure you can obtain?



Test how many times you can extend and retract the piston rod when using about 14 PSI (or 1 bar).
Then, do the same test using about 29 and about 36 PSI (or 2 and 2.5 bars).







Scissor Lift

Science
- Area
- Behavior of gases under pressure
- Forces

Design & Technology
- Assembling components
- Control of mechanisms
- Evaluating
- Using mechanisms – levers

Vocabulary
- Compression
- Cylinder
- Force
- Levers
- Manometer
- Pressure
- Pump
- Valve
- Weight

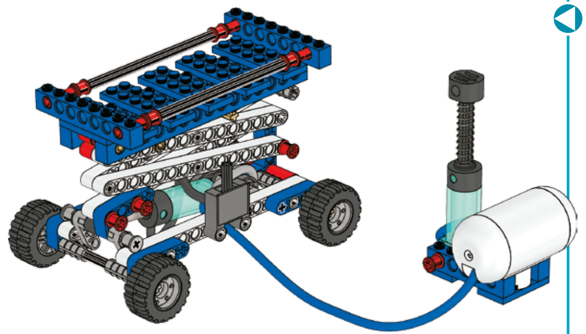
Connect

Scissor lifts are designed for easy and safe access to elevated positions and are often used where ladders are not an option. A scissor lift's work platform provides space for tools and movement, and can lift a heavy load.

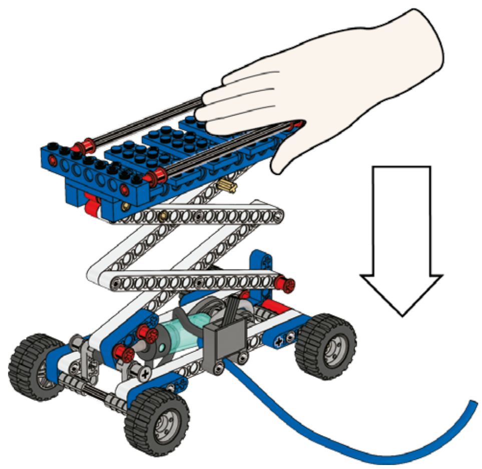
Build the scissor lift and investigate how its function is influenced by weight and height.

Construct

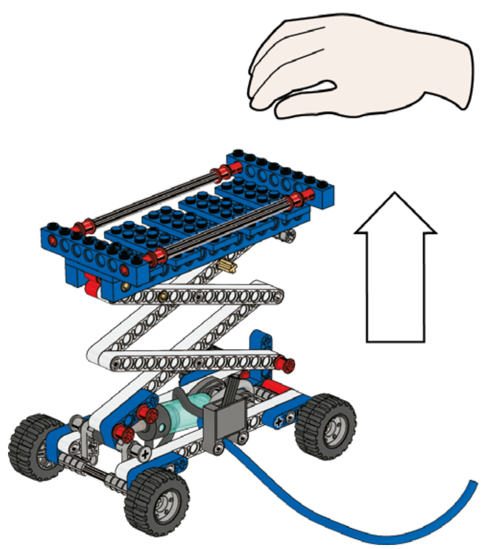
Build the Scissor Lift
(All of book 1A and book 1B to page 11, step 15)



- Pump air into the system and make sure the scissor lift rises smoothly.
- Press down on the platform of the raised scissor lift.



- When you let go, the platform should bounce back up again. If not, check for air leaks.
- Lower the scissor lift and empty the air tank.



Hint:
The easiest way to empty the air tank is to disconnect the tube going from the air tank to the valve.

Contemplate

Going Up?

Find out what influence weight and height have on the number of pumps needed to raise the scissor lift to its maximum height.

First, predict how many pumps are needed to raise scissor lift A to its maximum height. Record your predictions on the worksheet.

Then, test how many pumps are needed. Test several times to make sure your results are consistent. Record your findings on the worksheet.

Next, follow the same procedure for scissor lifts B, C, and D. Test each model several times to make sure your results are consistent.

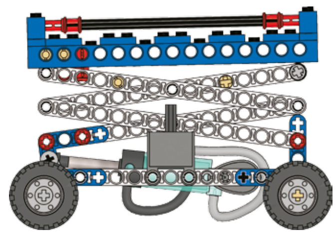
Scissor lift A (page 11, step 15) needs about 12 pumps.

Scissor lift B (page 12, step 16) needs about 20 pumps.

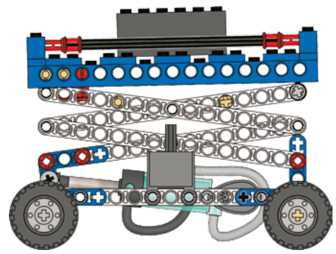
Scissor lift C (page 17, step 21) needs about 17 pumps.

Scissor lift D (page 18, step 22) needs about 28 pumps.

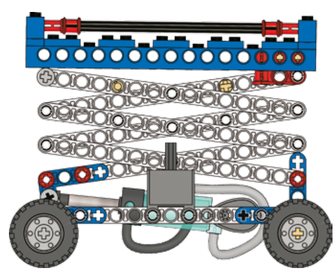
A



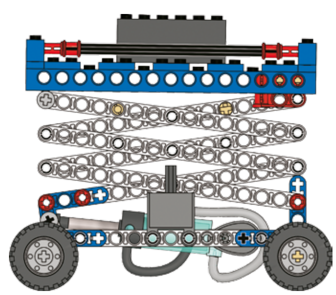
B



C



D



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

- What did you predict would happen and why?
- How does the scissor lift work?
  It is a series of first class levers each squeezing the next one. The pivot points are the pegs in the center of the beams.
- How did you make sure the tests were fair?
  Did you empty the air tank?

Continue

How much pressure is needed?

You know how many pumps are needed to raise the scissor lift to its maximum height. Now, add the manometer and find out how much pressure is needed.

First, predict how much pressure is needed to raise scissor lift A to its maximum height. Record your prediction on the worksheet.

Add the manometer.
Then, test how much pressure is needed.
Test several times to make sure your results are consistent.
Record your findings on the worksheet.

Next, follow the same procedure for scissor lifts B, C, and D.
Test several times to make sure your results are consistent.

Scissor lift A (page 11, step 15) needs a pressure of about 14 PSI or about 1 bar.

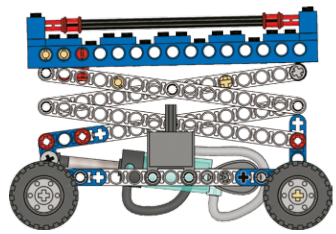
(One bar is equal to 14.50377 PSI, but the manometer is not this precise.)

Scissor lift B (page 12, step 16) needs a pressure of about 21 PSI (or about 1.5 bars).

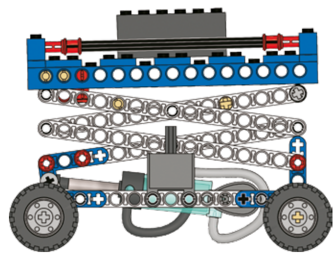
Scissor lift C (page 17, step 21) needs a pressure of about 20 PSI (or about 1.4 bars).

Scissor .ift D (page 18, step 22) needs a pressure of about 30 PSI (or about 2.1 bars).

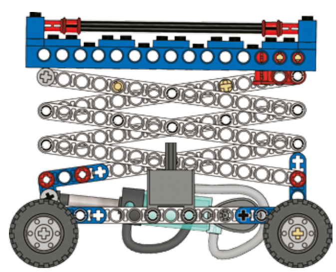
A



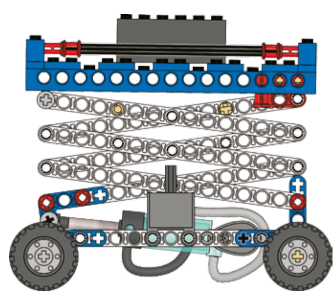
B



C



D



Optional: Further Investigations

- Why does the pressure drop immediately after the scissor lift has reached its maximum height?
  When the cylinder piston extends, the total area for compressed air has increased. The change in pressure of this new area results in a small pressure drop.

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

Notes:

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

Notes:

Scissor Lift

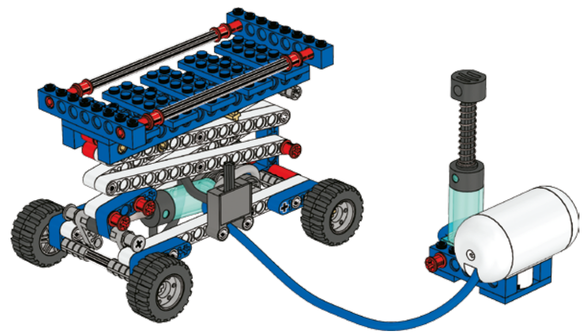
Name(s):

Build the scissor lift and investigate how its function is influenced by weight and height.

Build the Scissor Lift

(All of book 1A and book 1B to page 11, step 15)

- Pump air into the system and make sure the scissor lift rises smoothly.
- Press down on the platform of the raised scissor lift.
- When you let go, the platform should bounce back up again. If not, check for air leaks.
- Then, lower the scissor lift and empty the air tank.



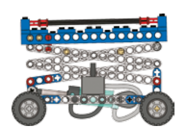
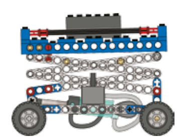
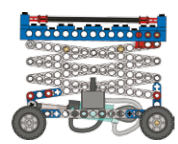
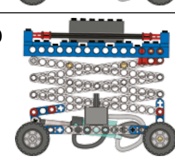
Going Up?

Find out what influence weight and height have on the number of pumps needed to raise the scissor lift to its maximum height.

First, predict how many pumps are needed to raise scissor lift A to its maximum height. Then, test how many pumps are needed.
Test several times to make sure your results are consistent.

Next, follow the same procedure for scissor lifts B, C, and D.

Test each model several times to make sure your results are consistent.

	My Prediction	My Findings
A 		
B 		
C 		
D 		

Explain your findings:

How much pressure is needed?

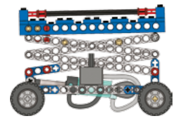
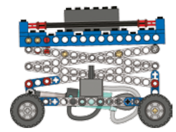
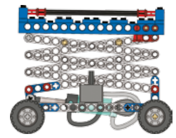
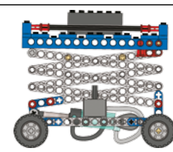
You know how many pumps are needed to raise the scissor lift to its maximum height. Now, add the manometer and find out how much pressure is needed.

First, predict how much pressure is needed to raise scissor lift A to its maximum height.

Add the manometer.
Then, test how much pressure is needed.
Test several times to make sure your results are consistent.

Next, follow the same procedure for scissor lifts B, C, and D.

Test each model several times to make sure your results are consistent.

	My Prediction	My Findings
A 		
B 		
C 		
D 		

Optional: My Amazing Pneumatic ______________ !

Invent a new and useful machine that uses the same mechanism as the scissor lift but does a different job.
Sketch it and explain the three most important features.

Optional: Further Research

Describe some of the industries and jobs for which the scissor lift could be used and what some of its limitations may be.

Scissor Lift

Name(s): ____________________ **Date:** ____________________

<table>
<tr><th>NGSS GOALS</th><th>
BRONZE</th><th>
SILVER</th><th>
GOLD</th><th>
PLATINUM</th></tr>
<tr><td colspan="5">1. Student work related to this Crosscutting Concept:
In this project, we tested how many pumps were required to lift two different scissor lift designs with and without weight. We explained our findings on our student worksheet.</td></tr>
<tr><td>Cause and effect - Mechanism and explanation:

Use cause and effect relationships to explain observations in designed systems.</td><td>• We explained similarities and/or differences in the number of pumps required to lift scissor lift A vs. B.
☐</td><td>• We met Bronze.
• We communicated what caused what we observed (the effect).
☐</td><td>• We met Silver.
• Our cause and effect explanations describe the roles of weight and height in our observations.
☐</td><td>• We met Gold.
• We identified additional ‘effects’ (such as force required to pump, time to lift, or loss of pressure) and proposed causes for those effects.
☐</td></tr>
<tr><td colspan="5">2. Student work related to this Practice:
In this project, we built a model of a scissor lift to test ideas about how much air is required to lift the mechanism to different heights with different loads.</td></tr>
<tr><td>Developing and using models:

Develop and use a model to test ideas about designed systems including those representing inputs and outputs.</td><td>• We built our scissor lift model.
• We pumped air into the system to make sure it moved smoothly.
• We checked the system for leaks.
☐</td><td>• We met Bronze.
• We completed our investigation of scissor lifts A and B.
☐</td><td>• We met Silver.
• We completed our investigation of scissor lifts C and D.
☐</td><td>• We met Gold.
• We proposed new design ideas to improve our scissor lift (lift more weight, lift higher, etc.).
☐</td></tr>
<tr><td colspan="5">3. Student work related to this Practice:
In this project, we invented a new and useful machine that uses the same mechanism as the scissor lift. We sketched our machine and described its three most important features.</td></tr>
<tr><td>Obtaining, evaluating, and communicating information:

Integrate qualitative and/ or quantitative information in written text with visual displays to clarify claims and findings.</td><td>• We sketched our new machine design.
☐</td><td>• We met Bronze.
• We explained one feature of our machine.
☐</td><td>• We met Silver.
• We explained two more features of our machine.
☐</td><td>• We met Gold.
• We created and shared our diagram and explanation with classmates.
• We revised our work and made it more clear for our classmates to understand.
☐</td></tr>
<tr><td colspan="5">Notes:</td></tr>
</table>

Robot Hand

Science
- Behavior of gases under pressure
- Forces
- Friction
- Measuring weight
- Scientific investigation

Design & Technology
- Assembling components
- Evaluating
- Testing before making improvements
- Using mechanisms – levers

Vocabulary
- Circumference
- Cylinder
- Force
- Grip
- Levers
- Manometer
- Mass
- Pressure
- Pump
- Valve
- Weight

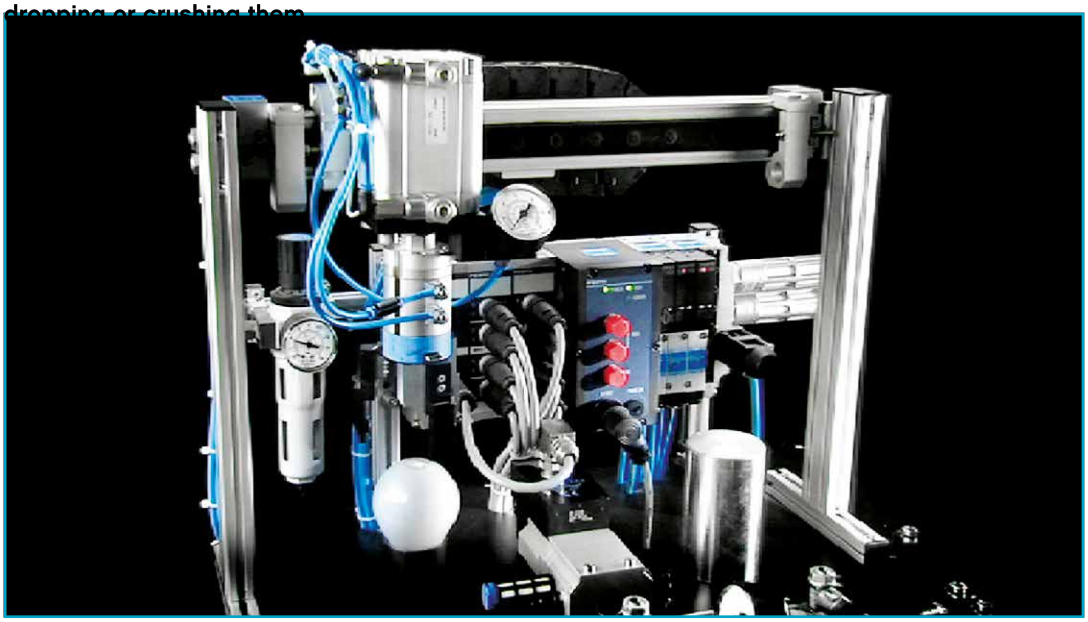
Other Materials Required
- A collection of small objects of different size and weight
- Plastic cup

Optional
- Modeling clay
- Rubber bands
- Weighing machine

Connect

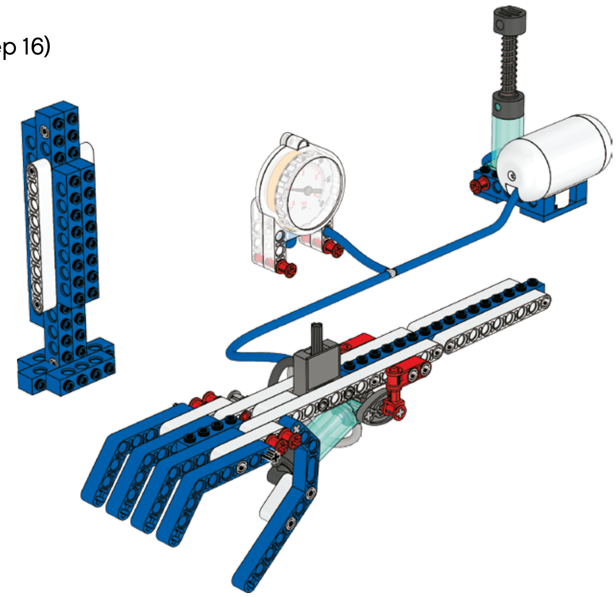
Industry and hospitals often need to handle and move objects that can be dangerous to touch by hand. Metal objects and fragile glass containers, for example, are often handled using pneumatic hands or grippers.

Build the robot hand and investigate what pressure is needed to hold different objects without dropping or crushing them.

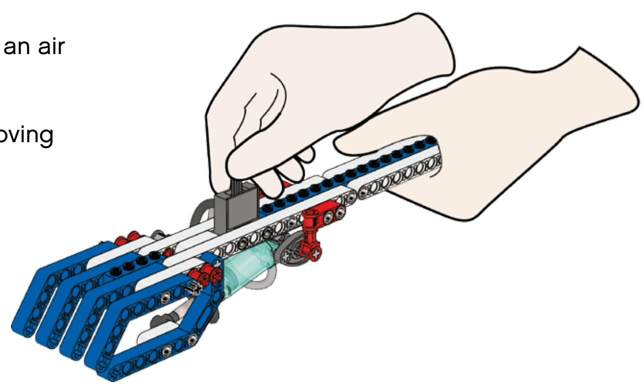


Construct

Build the Robot Hand and the Carrier
(All of book 2A and book 2B to page 10, step 16)



- Pump air into the system and use the manometer to detect whether there is an air leak.
- Try the valve settings and check all moving parts to ensure that they move freely.



- Then, open the hand and empty the air tank.

Hint:
The easiest way to empty the air tank is to disconnect the tube going from the air tank to the valve.

Contemplate

How good a grip?

The robot hand can pick up the carrier from two different sides – the smooth white side and the studded blue side. Find out how much pressure the robot hand needs to pick up the carrier.

First, predict how much pressure the robot hand A needs to lift carrier A.
Record your findings on the worksheet.

Then, test how much pressure is needed.
Test several times to make sure your results are consistent.
Record your findings on the worksheet.

Next, follow the same procedure for robot hands B, C, and D.
Test each model several times to make sure your results are consistent.

Robot hand A (page 10, step 16) needs a pressure of about 7 PSI (or about 0.5 bar).

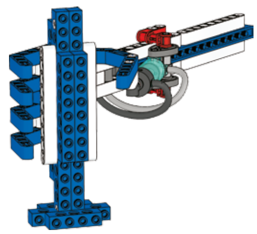
Robot hand B (page 10, step 16) needs a pressure of about 5 PSI (or about 0.4 bar).

Robot hand C (page 12, step 18) needs a pressure of about 17 PSI (or about 1.2 bars).

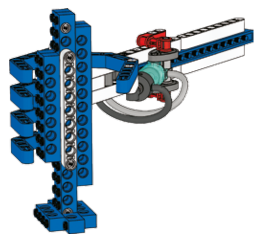
Robot hand D (page 12, step 18) needs a pressure of about 14 PSI (or about 1 bar).

Does weight have an effect?
When carrying extra weight, the type of surface does matter. Extra friction and gripping points on the load mean less crushing pressure is needed. This is safer and more efficient.

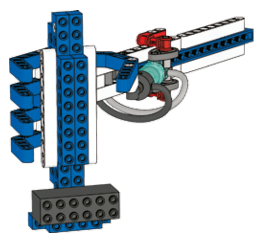
A



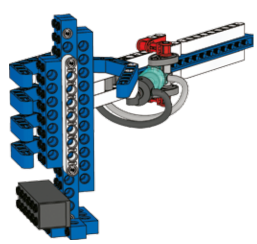
B



C



D



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

- What did you predict would happen and why?
- What type of lever is the gripping thumb?
  The gripping thumb is a third class lever.
- Where does the robot hand pivot?
  The pivot is at the wrist.
- What are the limitations of the robot hand's grip?
  The fingers and thumb are too slippery and do not have enough friction.
  The fingers do not bend in and grip like real fingers.

Continue

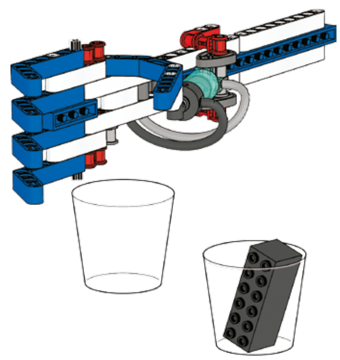
What else can the robot hand hold?

Place a paper or plastic cup on your desk or work area. Find a variety of different objects to put in the cup. Find out how much pressure is needed for the robot hand to pick up the cup.

First, predict how much pressure the robot hand needs to lift the different objects without damaging them.
Record your prediction on the worksheet.

Then, test how much pressure is needed.
Record your findings on the worksheet.

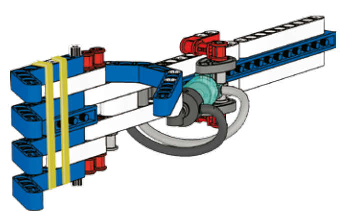
Test several times to make sure your results are consistent.



Hint:
Make an egg-shaped object out of modelling clay. Marks on the clay's surface can be used to record damage caused by pressure. But remember to cover the clay in plastic wrap to keep the elements clean.

Optional: Further investigations

Need a better grip?
Experiment by adding different materials to the robot hand for a better and safer grip that also causes less damage.



Observation Checklist Part 1

Science and Engineering Practices
Grade 6-8

Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.

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

Notes:

Observation Checklist Part 2

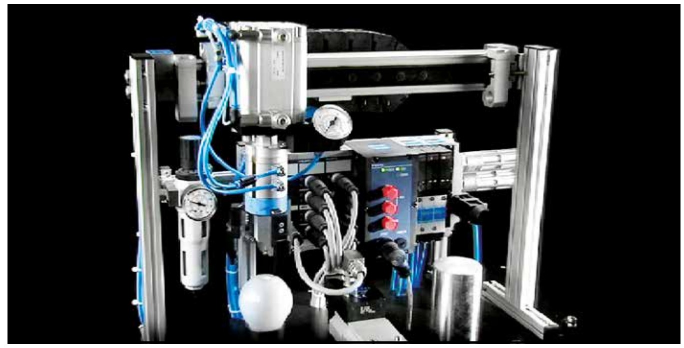
Science and Engineering Practices
Grade 6-8

Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.

		Name(s)										
Practice 5: I observed students using mathematics and computational thinking												
a	by including mathematical representations in their explanations and design solutions.											
b	by using an algorithm to solve a problem.											
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.											
Practice 6: I observed students constructing explanations and design solutions												
a	that included quantitative and qualitative relationships.											
b	that are based on scientific ideas, laws and theories.											
c	that connect scientific ideas, laws, and theories to their own observations.											
d	that apply scientific ideas, laws, and theories.											
e	to help optimize design ideas while making tradeoffs and revisions.											
Practice 7: I observed students engaging in arguments from evidence												
a	that compare and critique two arguments on the same topic.											
b	while respectfully providing and receiving critiques using appropriate evidence.											
c	while presenting oral or written statements supported by evidence.											
d	while evaluating different design solutions based on agreed-upon criteria and constraints.											
Practice 8: I observed students evaluating and communicating information												
a	when they read scientific text adapted for the classroom.											
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.											
c	when they created presentations about their investigations and/or design solutions.											

Notes:

Robot Hand

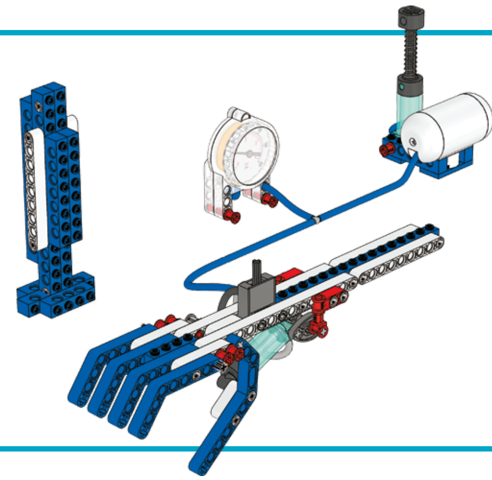


Name(s):

Build the robot hand and investigate what pressure is needed to hold different objects without dropping or crushing them.

Build the Robot Hand and the Carrier

(All of book 2A and book 2B to page 10, step 16)



- Pump air into the system and use the manometer to detect whether there is an air leak.
- Try the valve settings and check all moving parts to ensure that they move freely.
- Then open the hand and empty the air tank.

How good a grip?

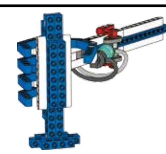
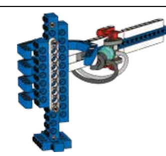
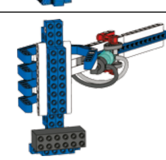
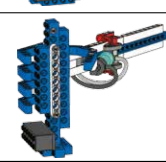
The robot hand can pick up the carrier from two different sides – the smooth white side and the studded blue side. Find out how much pressure the robot hand needs to pick up the carrier.

First, predict how much pressure the robot hand needs to lift carrier A.
Record your prediction.

Test how much pressure is needed.
Test several times to make sure your results are consistent.
Record your findings.

Next, follow the same procedure for robot hands B, C, and D.

Test each model several times to make sure your results are consistent.
Record your findings.

	My Prediction	My Findings
A 		
B 		
C 		
D 		

Explain your findings:

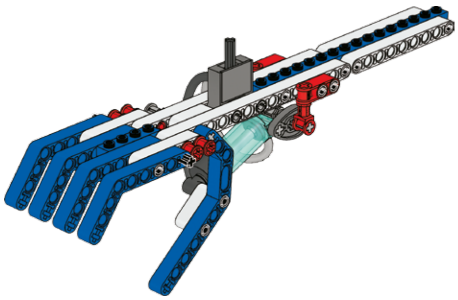
What else can the robot hand hold?

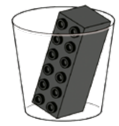
Place a paper or plastic cup on your desk or work area.
Find a variety of different objects to put in the cup.
Find out how much pressure is needed for the robot hand to pick up the cup.

First, predict how much pressure the robot hand needs to lift the different objects without damaging them.

Then, test how much pressure is needed.

Test several times to make sure your results are consistent.



Object	My Prediction	My Findings
A 		
B 		
C		
D		

Optional: My Amazing Pneumatic ______________ !

Invent a new and useful machine that uses the same mechanism as the robot hand but does a different job.
Sketch it and explain the three most important features.

Optional: Further Research

Describe some of the industries and jobs for which the robot hand could be used and what some of its limitations may be.

Robot Hand

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

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we invented a new and useful machine that uses the same mechanism as the robot hand but does a different job. We sketched and explained the three most important features.				
Structure and function: The way in which an object is shaped determine many of its properties and functions.	• We sketched our new machine design. ☐	• We met Bronze. • We explained one feature of our machine. ☐	• We met Silver. • We explained two more features of our machine. • For at least one of our features, we described how its shape affected how it functioned. ☐	• We met Gold. • We created and shared our diagram and explanation with classmates. • We revised our work and made it more clear for our classmates to understand. ☐
2. Student work related to this Practice: In this project, we carefully observed our robot hand lift a cup without damaging it. We used this observation to ask ourselves and our classmates questions about other objects our robot hand could lift.				
Asking questions and defining problems: Ask questions that arise from careful observation of phenomena to seek additional information.	• We predicted how much pressure our robot hand would need to lift a paper or plastic cup. • We measured the pressure needed by our robot hand to lift the cup. ☐	• We met Bronze. • We predicted and measured the amount of pressure our robot hand would need to lift a cup with a weight inside. ☐	• We met Silver. • We asked our selves and our classmates questions about other objects our robot hand could lift. • Our observations and questions helped us pick two more objects to test. ☐	• We met Gold. • We asked ourselves and our classmates questions that helped invent a new and useful machine that uses the same mechanism as the robot hand. ☐
3. Student work related to this Practice: In this project, we investigated how much pressure was required for our robot hand to pick up the carrier with and without weight from two different sides. We explained our findings on our student worksheet.				
Constructing explanations: Apply scientific ideas and evidence to construct an explanation for real world events.	• We completed the robot hand grip experiment from page one of our student worksheet. ☐	• We met Bronze. • We explained why the robot hand needed more pressure when there was extra weight on the carrier (C and D). ☐	• We met Silver. • We explained why the robot hand needed more pressure when it gripped the smooth white side of the carrier. ☐	• We met Gold. • We proposed at least one new experiment to test our explanations further (such as more weight or gripping different surfaces). ☐
Notes:				

Stamping Press

Science
- Area
- Behavior of gases under pressure
- Forces
- Scientific investigation

Design & Technology
- Assembling components
- Control of mechanisms
- Evaluating
- Properties of materials
- Using mechanisms – levers

Vocabulary
- Area
- Cylinder
- Efficiency
- Force
- Levers
- Manometer
- Mass
- Pressure
- Pump
- Valve

Other Materials Required
- Aluminium foil or plastic wrap
- Clay or small pieces polystyrene foam
- Graph paper
- Stopwatch or timer

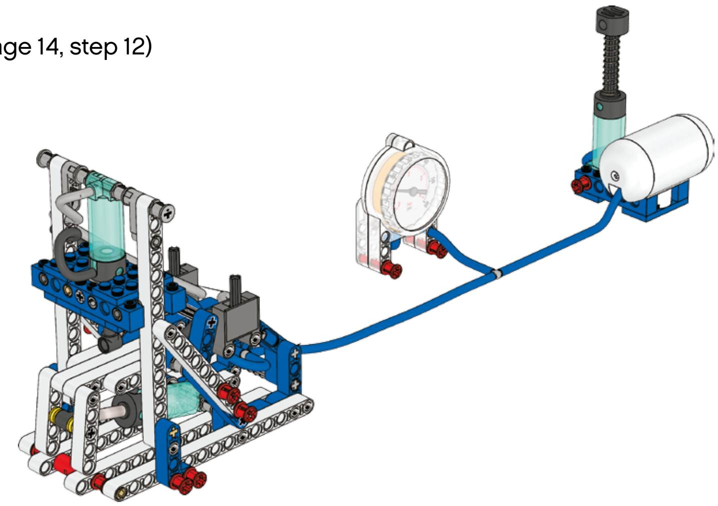
Connect

A stamping press stamps or presses a material into a new shape or size. To be as efficient as possible, the process needs to use the least amount of energy possible, yet work as fast as possible.

Build the stamping press and investigate how energy efficient it is.

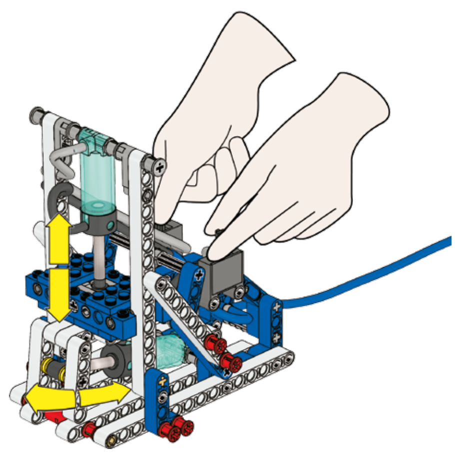
Construct

Build the Stamping Press
(All of book 3A and book 3B to page 14, step 12)



- Pump air into the system and use the manometer to detect whether there is an air leak.

- Try all valve settings and test the stamping press to determine if it can do all four possible strokes: press down, press up, ejector down, and ejector up. Make sure all moving parts move freely.



- Then, move the press up, the ejector forward, and empty the air tank.

Hint:
The easiest way to empty the air tank is to disconnect the tube going from the air tank to the valve.

Contemplate

How energy efficient is your press?

One complete work cycle is four 'strokes' in sequence: press down, press up, ejector down, and ejector up. Find out how repeated work cycles affect the pressure.

First, predict how repeated work cycles affect the loss of pressure when working with empty stamping press A.

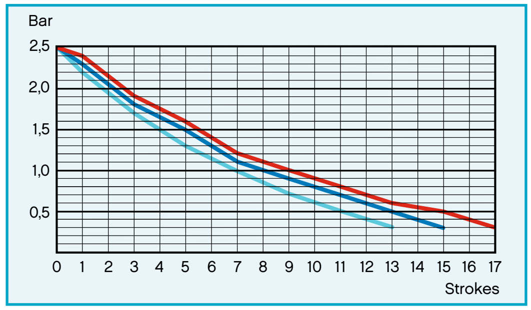
Record your predictions on the graph paper as a dotted line starting at about 36 PSI (or about 2.5 bar) and ending near zero. Remember it doesn't have to be a straight line.

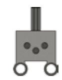
Then, test how stamping press A's repeated work cycles actually affect the loss of pressure.

Start with about 36 PSI (or about 2.5 bars of pressure). Test several times to make sure your results are consistent.
Record your findings on the graph paper.

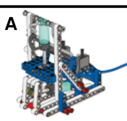
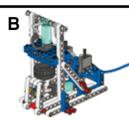
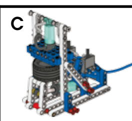
Next, follow the same procedure for stamping presses B and C.

Test each model several times to make sure your results are consistent.





Hint:
For a more accurate graph, record your findings after each stroke.

	A 	B 	C 
1	2.2	2.3	2.3
3	1.7	1.8	1.9
5	1.3	1.5	1.6
7	1.0	1.1	1.2
9	0.7	0.9	1.0
11	0.5	0.7	0.8
13	0.3	0.5	0.6
15		0.3	0.5
17			0.3

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

- What did you predict would happen and why?
- How does the stamping press work, and which type of lever is used?
  The stamper delivers a direct press and the ejector uses a complex second-class lever.
- How many complete work cycles can you do when starting with about 36 PSI (or about 2.5 bars)?
  About three complete work cycles can be completed with about 2.5 bars of pressure.

Continue

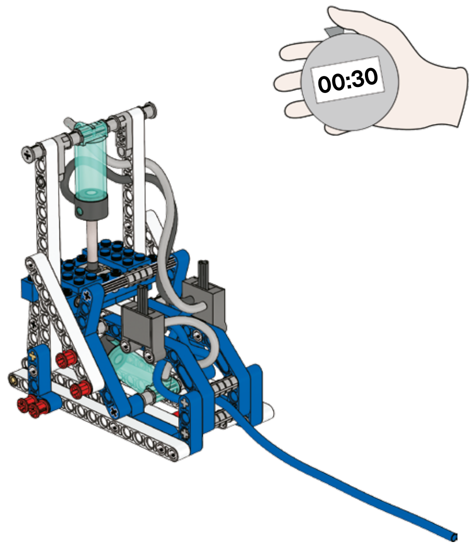
How good are you at operating the press?

The faster you can operate the empty stamping press, the more cost efficient it will be. Find out how many complete work cycles you can finish within 30 seconds.

First, predict how many complete work cycles you can finish within 30 seconds when using an empty stamping press.
Record your predictions on the worksheet.

Then, test how many complete work cycles you actually finished.
Test several times to make sure your results are consistent.
Record your findings on the worksheet.

Next, try pressing different objects of your choice and compare the number of complete work cycles you are able to finish.
Test each object several times to make sure your results are consistent.



Hint:
Before you start, it is a good idea to decide if you are starting with an empty or full air tank.

Hint:
To help overcome the loss of pressure, you could build a compressor.

Observation Checklist Part 1

Science and Engineering Practices
Grade 6-8

Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.

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

Notes:

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

Notes:

Stamping Press

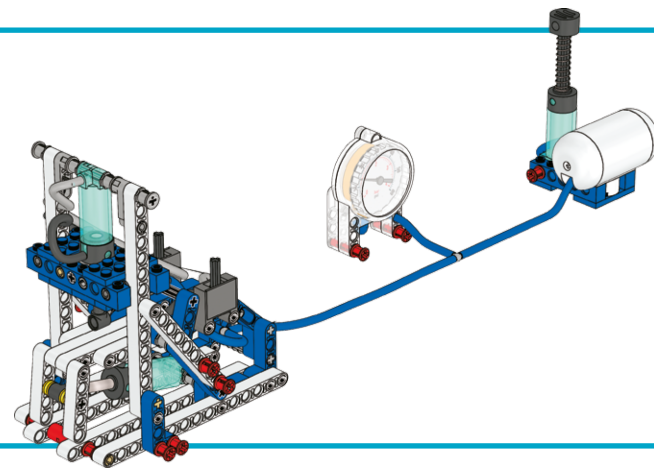
Name(s):

Build the stamping press and investigate how energy efficient it is.

Build the Stamping Press

(All of book 3A and book 3B to page 14, step 12)

- Pump air into the system and use the manometer to detect whether there is an air leak.
- Try all valve settings and test if the stamping press can do all four possible strokes: press down, press up, ejector down, and ejector up. Make sure all moving parts move freely.
- Then, move the press up, the ejector forward, and empty the air tank.



How energy efficient is your press?

One complete work cycle is four 'strokes' in sequence: press down, press up, ejector down, and ejector up. Find out how repeated work cycles affect loss of pressure.

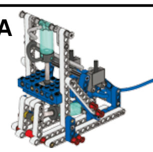
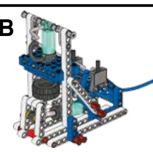
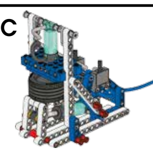
First, predict how repeated work cycles affect the loss of pressure when working with empty stamping press A.

Then, test how stamping press A's repeated work cycles actually affect the loss of pressure.
Start with 36 PSI (or 2.5 bars of pressure). Test several times to make sure your results are consistent.

Next, follow the same procedure for stamping presses B and C.

Test each model several times to make sure your results are consistent.

Record your results on graph paper.

	A 	B 	C 
1			
3			
5			
7			
9			
11			
13			
15			
17			

Explain your findings:

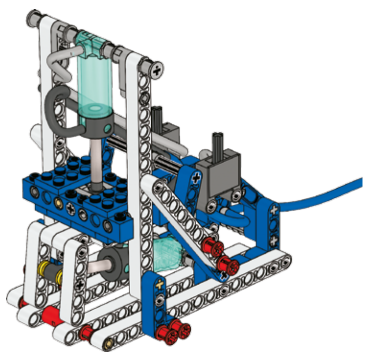
How good are you at operating the stamping press?

The faster you can operate the empty stamping press, the more cost efficient it will be. Find out how many complete work cycles you can finish within 30 seconds.

First, predict how many complete work cycles you can finish within 30 seconds when using an empty stamping press. *Record your predictions on the worksheet.*

Then, test how many complete work cycles you actually finished. *Record your findings on the worksheet.*

Next, try pressing different objects of your own choice and compare the number of complete work cycles you are able to finish.



	My Prediction	My Findings
Test 1		
Test 2		
Test 3		

Optional: My Amazing Pneumatic ______________ !

Invent a new and useful machine that uses the same mechanisms as the stamping press but does a different job. Sketch it and explain the three most important features.

Optional: Further Research

Describe some of the industries and jobs for which the stamping press could be used and what some of its limitations may be.

Stamping Press

Name(s): ____________________ **Date:** ____________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we used a graph to track the loss of pressure in our stamping press after repeated work cycles.				
Energy and matter - Flows, cycles, and conservation: Tracking energy in and out of a system helps understand the system's possibilities and limitations.	• We created a graph of our results on graph paper from the stamping machine experiment on page one of our student worksheet.	• We met Bronze. • We labeled our graph's axes with pressure and strokes.	• We met Silver. • We labeled the lines for each experiment (A,B, and C) on our graph with different colors or line styles. • We used our graph to help us explain our findings in the experiments.	• We met Gold. • We used our graph to help us propose a new experiment for our stamping machine.
2. Student work related to this Practice: In this project, we investigated the loss of pressure in our stamping press after repeated work cycles.				
Planning and carrying out investigations: Collect data to test design solutions under a range of conditions.	• We completed the experiment for stamping press A. • We recorded our pressure measurements for the odd number strokes indicated on our data table (page one of the student worksheet).	• We met Bronze. • We completed and recorded the measurements for our experiment on stamping press B.	• We met Silver. • We completed and recorded the measurements for our experiment on stamping press C.	• We met Gold. • We proposed a new model for 'My Amazing Pneumatic'.
3. Student work related to this Practice: In this project, we used data to help us find similarities and differences in the pressure loss of three different stamping machine scenarios (A,B, and C). We used these data as evidence when we explained our findings.				
Analyzing and interpreting data: Analyze and interpret data to determine similarities and differences in findings.	• We reviewed our data tables and graphs. • We wrote an explanation for our findings.	• We met Bronze. • We identified at least one similarity and/or difference between the data in our three experiments.	• We met Silver. • We identified at least two similarities and/or difference between the data in our three experiments.	• We met Gold. • We compared our data analysis with our classmates. • We revised our work and made it more clear for our classmates to understand.

Notes:

Robot Arm

Science
- Area
- Behavior of gases under pressure
- Friction
- Scientific investigation

Design & Technology
- Assembling components
- Evaluating
- Controlling of mechanisms
- Testing before making improvements
- Using mechanisms – levers

Vocabulary
- Area
- Cylinder
- Grip
- Levers
- Manometer
- Mass
- Pressure
- Pump
- Valve

Other Materials Required
- A collection of small objects of different size and weight
- Several small pieces of crumpled paper
- Graph paper

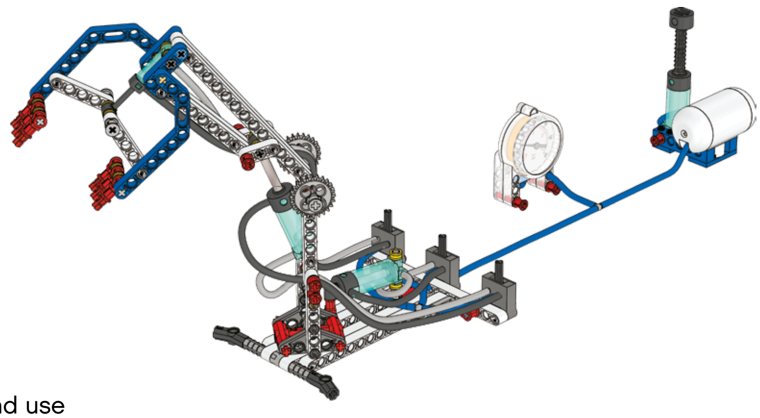
Connect

Robotic arms are used for jobs that involve picking up, moving, and placing objects. Usually they do jobs that are difficult or repetitive, and need to be done quickly and efficiently. To achieve maximum efficiency, the picking and placing sequence needs to be decided beforehand.

Build the robot arm and investigate how to make the most energy efficient sequence of strokes.

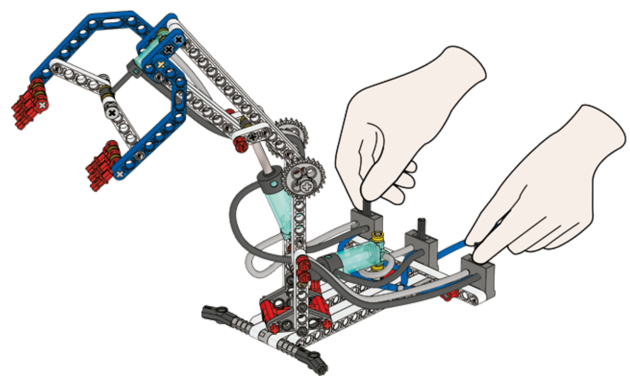
Construct

Build the Robot Arm
(All of book 4A and book 4B to page 19, step 19)



- Pump air into the system and use the manometer to detect whether there is an air leak.

- Try all valve settings and check all moving parts to ensure that they move freely.



- Turn the arm to its resting position: turned to the far right, arm up, grippers open. Then, empty the air tank.

Hint:
The easiest way to empty the air tank is to disconnect the tube going from the air tank to the valve.

Contemplate

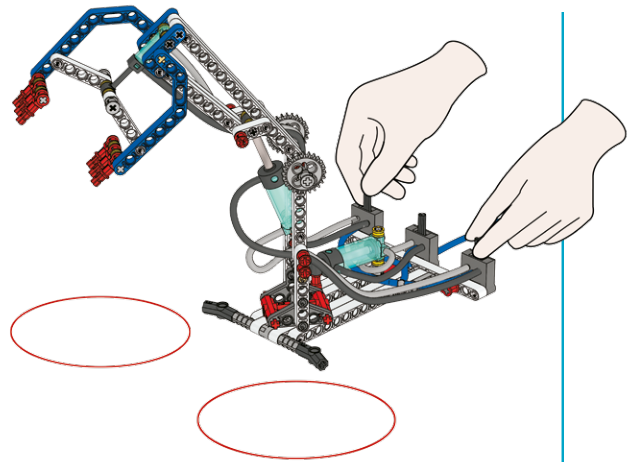
What is the most energy efficient sequence?

Find out which sequence is the most energy efficient for picking and placing objects.

First, predict which sequence of strokes is the most energy efficient at picking and placing a piece of paper. Your sequence must start in the resting position, use all six movements at least once, and then return to the resting position.
Record your predictions on the worksheet.

Then, test your sequence of strokes and note the loss of pressure after each stroke.
Start with about 36 PSI (or 2.5 bars of pressure).
Record your findings on the worksheet and graph paper.

Test several times to make sure your results are consistent.
Then, change the order of the strokes and try again. Is your sequence more or less efficient?

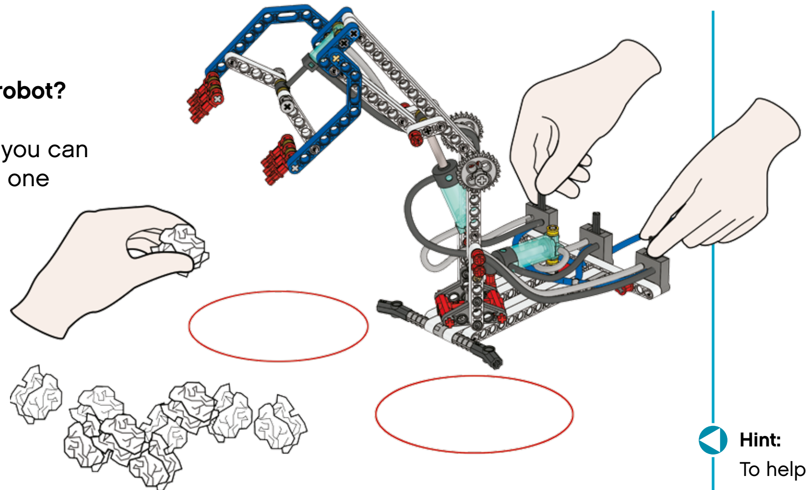


Stroke	My Sequence
A	Arm down
B	Grip close
C	Arm up
D	Arm turn left
E	Arm down
F	Grip open
G	Arm up
H	Arm turn right

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

- What did you predict would happen and why?
  It takes eight strokes to complete the work cycle and return to the resting position.
  If the object is dropped without lowering the arm it can be done in six strokes.
- What type of lever is the gripper?
  What type of lever is the arm lift?
  The gripper is a complex third class lever linkage. The arm lift is a third class lever, too.
- Explain the data shown on the pressure graph?
  The small cylinder uses much less air resulting in less pressure loss than the big cylinders. See Stroke B and F.

Continue



How good are you at operating the robot?

Find out how quickly and accurately you can pick and place pieces of paper from one circle to another

First, predict how many pieces of paper you can accurately place inside the circle within 30 seconds.
Record your predictions on the worksheet.

Then, test how many pieces of paper you actually place accurately inside the circle within 30 seconds.
Record your findings on the worksheet.

Repeat the test three times to see if your speed and accuracy improve.
Record your results after each test.

Optional: How about new grippers?
Design and make your own grippers that will help you to pick and place different objects of your choice.

Hint:
To help overcome the loss of pressure, you could build a compressor.

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

Notes:

Observation Checklist Part 2

Science and Engineering Practices
Grade 6-8

Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.

		Name(s)										
	Practice 5: I observed students using mathematics and computational thinking											
a	by including mathematical representations in their explanations and design solutions.											
b	by using an algorithm to solve a problem.											
c	by using concepts such as ratio, rate, percent, basic operations, or simple algebra.											
	Practice 6: I observed students constructing explanations and design solutions											
a	that included quantitative and qualitative relationships.											
b	that are based on scientific ideas, laws and theories.											
c	that connect scientific ideas, laws, and theories to their own observations.											
d	that apply scientific ideas, laws, and theories.											
e	to help optimize design ideas while making tradeoffs and revisions.											
	Practice 7: I observed students engaging in arguments from evidence											
a	that compare and critique two arguments on the same topic.											
b	while respectfully providing and receiving critiques using appropriate evidence.											
c	while presenting oral or written statements supported by evidence.											
d	while evaluating different design solutions based on agreed-upon criteria and constraints.											
	Practice 8: I observed students evaluating and communicating information											
a	when they read scientific text adapted for the classroom.											
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.											
c	when they created presentations about their investigations and/or design solutions.											

Notes:

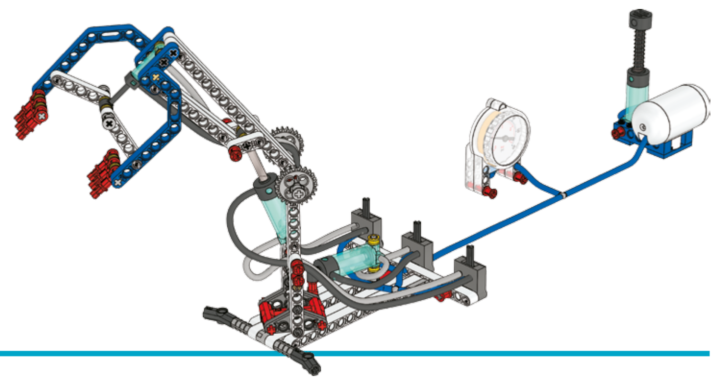
Robot Arm

Name(s):

Build the robot arm and investigate how to make the most energy efficient sequence of strokes.

Build the Robot Arm

(All of book 4A and book 4B to page 19, step 19)



- Pump air into the system and use the manometer to detect whether there is an air leak.
- Try all valve settings and check all moving parts to ensure that they move freely.
- Turn the arm to its resting position: turned to the far right, arm up, and grippers open. Then, empty the air tank.

What is the most energy efficient sequence?

Find out which sequence is the most energy efficient for picking and placing objects.

First, predict which sequence of strokes is the most energy efficient at picking and placing a piece of paper. Your sequence must start in the resting position, use all six movements at least once, and then return to the resting position.

Then, test your sequence of strokes and note the loss of pressure after each stroke.
Start with about 36 PSI (or 2.5 bars of pressure).

Test several times to make sure your results are consistent.
Record your findings on graph paper.
Change the sequence of strokes. Test your new sequence to determine if it is more or less efficient.

Stroke	My Sequence
A	
B	
C	
D	
E	
F	
G	
H	

Explain your findings:

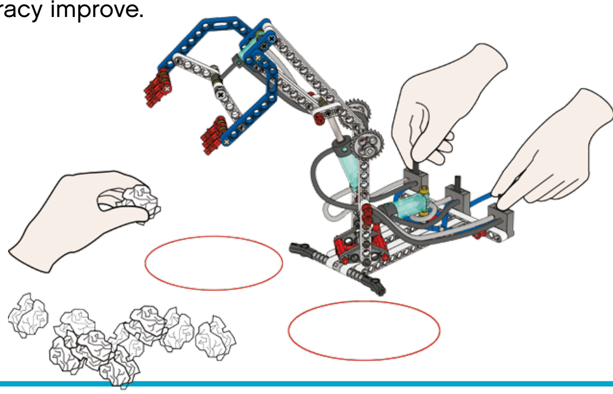
How good are you at operating the robot?

Find out how quickly and accurately you can pick and place pieces of paper from one circle to another circle.

First, predict how many pieces of paper you can accurately place inside the circle within 30 seconds.

Then, test how many pieces of paper you can accurately place inside the circle within 30 seconds.

Repeat the test three times to see if your speed and accuracy improve.



	My Prediction	My Findings
Test 1		
Test 2		
Test 3		

Optional: My Amazing Pneumatic ________________ !

Invent a new and useful machine that uses the same mechanisms as the robot arm but does a different job. Sketch it and explain the three most important features.

Optional: Further Research

Describe some of the industries and jobs for which the robot arm can be used and what some of its limitations may be.

Robot Arm

Name(s): ____________________ **Date:** ____________________

NGSS GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
1. Student work related to this Crosscutting Concept: In this project, we tried different movement patterns for our robot arm in order to find the most energy efficient sequence.				
Patterns: Observed patterns in events guide organization and classification.	• We wrote down our sequence of steps to pick up and place an object with our robot arm. ☐	• We met Bronze. • We recorded our findings on graph paper. • We looked for patterns on our graph to help us find the parts of our sequence that lost the most pressure. ☐	• We created a graph of a new sequence. • We looked for patterns in our graph to find where most of the pressure was lost. • We determined which sequence was best. ☐	• We met Gold. • We used patterns in both graphs to propose a different sequence that even more efficient. ☐
2. Student work related to this Practice: In this project, we invented a sequence of steps to move our robot arm efficiently.				
Using mathematics and computational thinking: series of ordered steps) to solve a problem.	• We created a sequence of steps to pick up and place objects. ☐	• We met Bronze. • We tested our sequence several times to make sure the results are consistent. ☐	• We met Silver. • We created a second sequence to test. ☐	• We met Gold. • We identified which sequence was best and explained our findings on page one of our student worksheet. ☐
3. Student work related to this Practice: In this project, we developed a sequence of steps to move our robot arm quickly. We evaluated our idea and compared it with our classmates.				
Engaging in argument from evidence: Evaluate competing design solutions based on agreed-upon design criteria.	• We developed a sequence of steps to pick and place pieces of paper quickly from one circle to another. ☐	• We met Bronze. • We predicted how many pieces of paper our robot arm could pick and place in 30 seconds. ☐	• We met Silver. • We tested our prediction three times and recorded the results. ☐	• We met Gold. • We compared our results with our classmates and proposed a new sequence of steps to improve our own work. ☐

Notes:

Introduction to the Designing and Making Activities

When is it best to use these?

They are ideal to use after you have worked on the principle and main activities and wish to find out how well your students can find and apply knowledge in designing and problem-solving. Each assignment is cross-referenced to the principle and main models. Students will creatively adapt their previous experiences with pneumatic concepts to solve the design task.

How to use them?

The assignment page is intended to be printed and handed out to your students. The page describing objectives, motivation, etc. is for you.

How to customize the designing and making activities to fit your students.

For the less experienced designers, or where you may need more control over materials, hand out the assignment while providing a specific design brief. A design brief can limit the range of possible solutions, and make it easier to compare the various ideas that students come up with. For experienced designers, just giving students the assignment section should be enough for them to start designing.

Dinosaur

The Assignment

A small production studio needs a dinosaur for a new film. Although they could use computer-generated images for the dinosaur, the studio has found that true-to-life, full-size moving models of dinosaurs have greater appeal.
The dinosaur must remain stationary; however, parts of it must move as it acts out various scenes.

Your task is to design and make a dinosaur model that has pneumatic movement and will work in a film scene.

Problem Solving Activity: ____________________

Name(s): ____________________ **Date:** ____________________

GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
Design Brief: Understand the problem, develop prototypes to solve it, test those prototypes and revise your design to make it better.	• Our design met the goals or criteria defined by the activity. ☐	• We met Bronze • We tested our prototype multiple times. • We made at least one improvement. ☐	• We met Silver • We made at least two improvements. ☐	• We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements. ☐
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	• We started the activity and have at least one possible solution that looks reasonable. ☐	• We brainstormed two to three ideas. • We built a working model to solve the problem. ☐	• We brainstormed more than three ideas. • We built an effective model to solve the problem. ☐	• We brainstormed many ideas. • We built and tested prototypes for at least two ideas. • We built an original and effective model that solves the problem. ☐
Collaboration: Work is shared effectively and the team encourages and helps each other.	• We sometimes worked together well but some team members did more work than others or we needed help from the teacher to resolve some disagreements. ☐	• We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members. ☐	• We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose. ☐	• We worked together unusually well, overcoming unexpected obstacles by working together as a team. • We actively helped and supported each other. • We addressed issues that arose with honest, constructive feedback. ☐

Notes:

Dinosaur

Objectives
Applying knowledge of:
- Animatronics
- Levers
- Product and services
- Pneumatics
- Applying principles of fair testing and product reliability

Other Materials Required
- Decorative materials

Motivation
- Instruct students to look at the pictures of dinosaurs or search the Internet to learn more about the appearance, shape, and form of dinosaurs from different periods.

Relating Knowledge, Skill, and Understanding to the Task at Hand
Instruct the students to think about…
- how you might create the dinosaur.
- which parts of your dinosaur will move and how you can achieve this movement.
- how you could decorate your dinosaur so that it looks as real as possible.

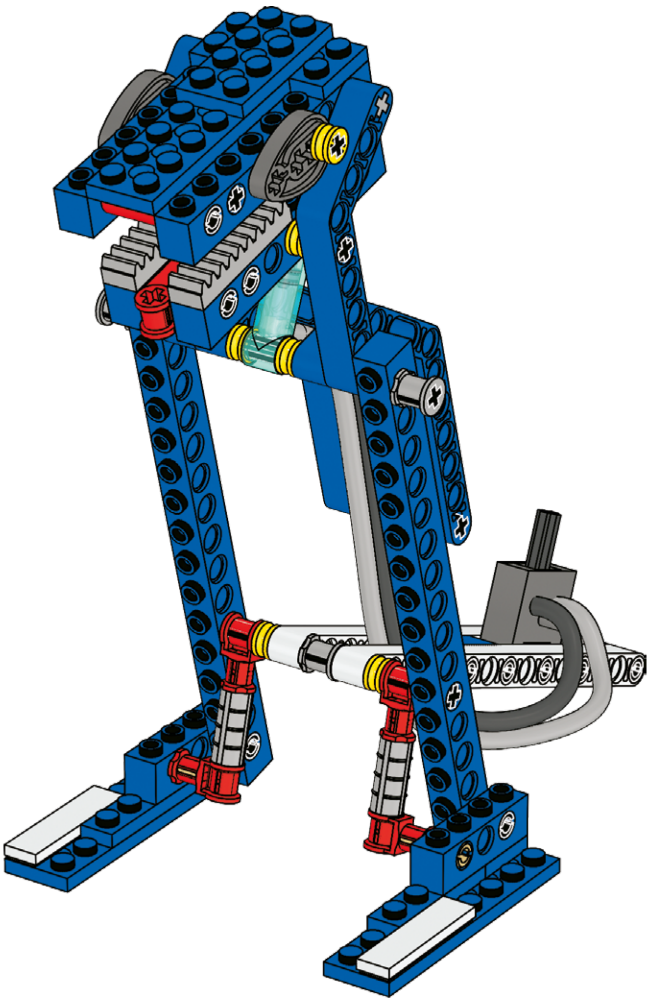
Encouraging Reflection
While the designing and making is in progress, encourage students to discuss if the movements of their dinosaurs make sense in terms of a film scene.

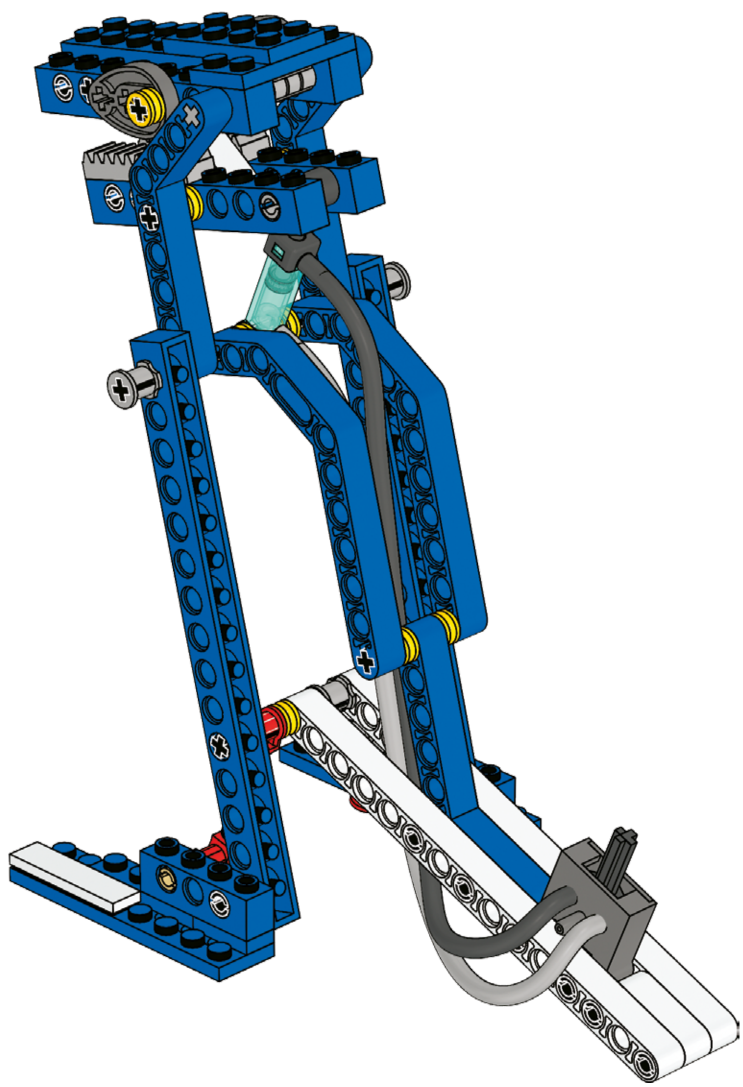
When the activity is finished, encourage the students to evaluate their work.
- How do the various dinosaur parts work?
- How good is the overall design of the dinosaur? Is the design reliable?
- Is the dinosaur efficient? Test this with the manometer.
- How is the model decorated to look like a dinosaur?
- What does the layout of the film scene look like and how would it appeal to a cinema audience?

Need help?
Look at:

Robot Arm

Principle models
for levers





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

Notes:

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

Notes:

Scarecrow

The Assignment

A local organic farmer has a lot of problems with birds eating his crops. He knows from experience that when he runs into his field waving his arms wildly and jumping up and down the birds fly away. Shouting at the birds without the movement, however, has little effect. He has tried using a conventional scarecrow, which does not move. Although it frightened the birds away in the beginning, they soon became used to it and it no longer makes any difference.

Your task is to design and make a pneumatic scarecrow model that moves in a way that will scare off the birds that are trying to eat the farmer's crops.

Self-Assessment

Problem Solving Activity: ____________________

Name(s): ____________________ **Date:** ____________________

GOALS	 BRONZE	 SILVER	 GOLD	 PLATINUM
Design Brief: Understand the problem, develop prototypes to solve it, test those prototypes and revise your design to make it better.	• Our design met the goals or criteria defined by the activity.	• We met Bronze • We tested our prototype multiple times. • We made at least one improvement.	• We met Silver • We made at least two improvements.	• We met Gold • We tested at least two different designs. • We picked the best design, tested it, and made several improvements.
Creativity: Come up with inventive and creative solutions to problems. Consider multiple solutions.	• We started the activity and have at least one possible solution that looks reasonable.	• We brainstormed two to three ideas. • We built a working model to solve the problem.	• We brainstormed more than three ideas. • We built an effective model to solve the problem.	• We brainstormed many ideas. • We built and tested prototypes for at least two ideas. • We built an original and effective model that solves the problem.
Collaboration: Work is shared effectively and the team encourages and helps each other.	• We sometimes worked together well but some team members did more work than others or we needed help from the teacher to resolve some disagreements.	• We generally worked together well, providing help and support to each other. • The work was shared fairly evenly among the group members.	• We worked together well, providing help and support to each other. • The work tasks were shared evenly. • We addressed issues that arose.	• We worked together unusually well, overcoming unexpected obstacles by working together as a team. • We actively helped and supported each other. • We addressed issues that arose with honest, constructive feedback.

Notes:

Scarecrow

Objectives

Applying knowledge of:
- Animatronics
- Levers
- Product and services
- Pneumatics
- Applying principles of fair testing and product reliability

Other Materials Required

- Decorative materials

Motivation

- Instruct students to look at the picture of the scarecrow or search the Internet to learn about the appearance, shape, and form of traditional and unconventional scarecrows.

Relating Knowledge, Skill, and Understanding to the Task at Hand

Instruct students to think about…
- how you might create a scarecrow.
- which parts of your scarecrow will move and how you can achieve this movement.
- how you will decorate your scarecrow so that it looks as real as possible.

Encouraging Reflection

While the designing and making is in progress, encourage students to discuss if the movements of the scarecrow make sense in terms of scaring off birds.

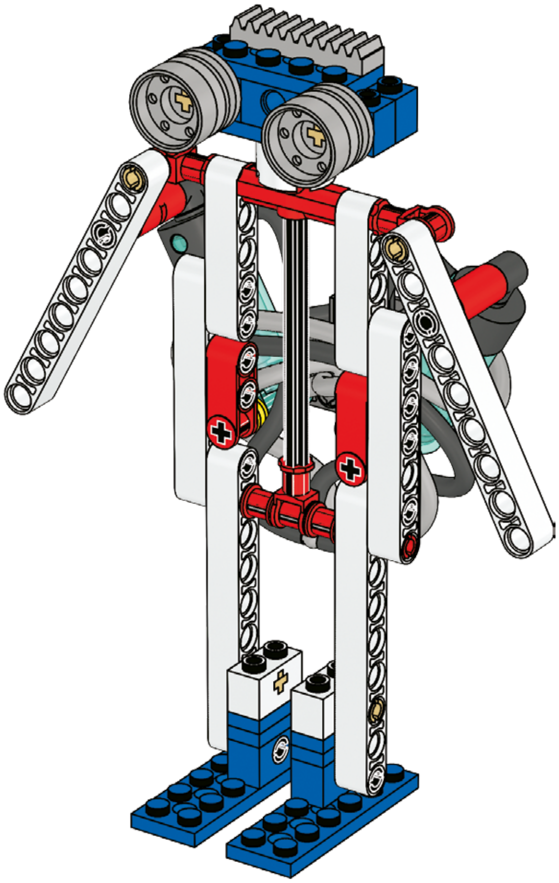
When the activity is finished, encourage students to evaluate their work.

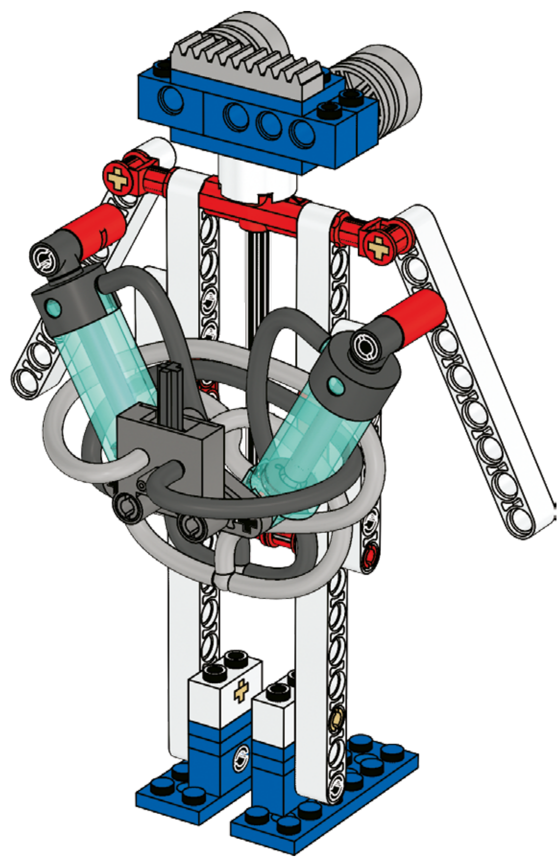
- How do the various scarecrow parts work?
- How good is the overall design of the scarecrow? Is the design reliable?
- Is the scarecrow efficient? Test this with the manometer.
- How is the model decorated to look like a scarecrow?

Need help?
Look at:

Robot Hand

Principle models
for levers





Observation Checklist Part 1

Science and Engineering Practices
Grade 6-8

Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.

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c	to distinguish between cause and effect vs. correlational relationships.											
d	by using statistics and probability such as mean and percentage.											
e	to determine similarities and differences in findings.											
f	to determine a way to optimize their solution to a design problem.											

Notes:

Observation Checklist Part 2

Science and Engineering Practices
Grade 6-8

Use the Bronze (1), Silver (2), Gold (3), and Platinum (4) proficiency level descriptions, or another assessment scale that is relevant to your school context.

		Name(s)										
Practice 5: I observed students using mathematics and computational thinking												
a	by including mathematical representations in their explanations and design solutions.											
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a	when they read scientific text adapted for the classroom.											
b	when they read or wrote information in combinations of text, graphs, diagrams, and other media.											
c	when they created presentations about their investigations and/or design solutions.											

Notes:

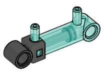
Glossary

A	**Air tank**	A storage tank, or reservoir, for compressed air.
B	**Balanced force**	An object under the influence of balanced forces is at rest or moves at a uniform velocity.
	Bar	A common metric unit used for pressure measurement 1 bar equals 14.50377 PSI or 100,000 Pascals.
C	**Circumference**	The distance around a circle.
	Compressibility	The characteristic of substances, such as gases, that can be compressed so that they occupy less space to fit into smaller containers.
	Compressor	A mechanism used to compress air; A compressor could be motorized or operated manually.
	Cylinder	A rigid barrel with closed ends containing a piston and a piston rod; When compressed air enters the cylinder, it expands against the piston, producing force and creating movement.
	Cylinder Piston	See Piston.
E	**Efficiency**	A measure of how much of the force that goes into a machine comes out as useful work. Friction often wastes a lot of energy reducing the efficiency of a machine.
	Energy	The capacity to do work.
F	**Fair Testing**	Measuring the performance of a machine by comparing its performance under different conditions.
	Force	A push or a pull in a particular direction that can be applied to an object; The force created by a pneumatic cylinder is the product of the air pressure times the area of the piston.
	Friction	The resistance met when one surface is sliding over another; For example, when an axle is turning in a hole or when you rub your hands together friction occurs.
G	**Grip**	Hold firmly; The grip between two surfaces depends on the amount of friction between them; Tires grip dry road surfaces better than wet road surfaces.

K	**Kinetic energy**	The energy of an object that is related to its speed or movement; The faster it is travelling, the more kinetic energy it has.
L	**Lever**	A bar that pivots about a fixed point when an effort is applied to it.
	Lever, first-class	A lever with the pivot between the effort and the load; A long effort arm and short load arm amplifies the force at the load arm. For instance prying the lid off a paint can. The Scissor Lift uses a first-class lever.
	Lever, second-class	A lever with the load between the effort and the pivot; This lever amplifies the force from the effort to make lifting the load easier; for instance a wheelbarrow.
	Lever, third-class	A lever with the effort between the load and the pivot; This lever amplifies the speed and distance the load moves compared to the effort. The thumb on the hand is a third-class lever.
	Linkages	A mechanical linkage carries movement and forces through a series of rods or beams connected by moving pivot points. The Scissor Lift contains many linkages.
M	**Machine**	A device that makes work easier to accomplish and/or faster to complete. It usually contains mechanisms.
	Manometer	A manometer is an instrument used to measure pressure. The LEGO® manometer gives you a pressure reading in both bar and PSI.
	Mass	Mass is the quantity of matter in an object. Mass is often confused with weight.
	Mechanism	A simple arrangement of components that transforms the size or direction of a force, and the speed of its output, such as a lever or two gears meshing.
P	**Piston**	A solid disk that moves inside a cylinder in response to changing pressure.
	Piston rod	A rod connected to a piston and extending outside a cylinder; When the piston moves inside the cylinder, the piston rod also moves.
	Pivot	The point around which something turns or rotates, such as the pivot of a lever; The pivot of a pair of scissors is the screw or rivet holding it together.
	Pneumatic	Related to the use of compressed air.
	Pneumatic circuit	The path of compressed air through a system of pneumatic components.
	Potential energy	Stored energy. Compressed air has potential energy that can be used to do work when it expands against a piston in a cylinder.

	Power	The rate at which a machine does work (work divided by time).
	Pressure	The amount of force exerted on a unit area. Atmospheric pressure at sea level is approximately 15 pounds per square inch (PSI). We are so used to this pressure we don't even notice it! The scientific unit for pressure is the pascal (Pa) and 1 Pa is 1 newton per square meter. A newton is quite a small force and a square meter is a large area so the force per unit area of 1Pa is tiny. In fact it takes almost 7000 Pa to exert 1 PSI and 100 000 Pa to exert atmospheric pressure.
	PSI	Pounds forced per square inch. PSI is a common unit used for pressure measurement. 1 PSI equals 6894.76 Pascals.
	Pump	A device that applies a force to a gas or liquid, such as air or water, to create pressure or movement.
S	**Sequencing**	Setting up actions to happen in the right order and at the right time intervals.
T	**Tube**	Flexible, hollow cylindrical material used to transport a gas or liquid, such as compressed air or water.
V	**Valve**	A device that accepts compressed air and directs its flow through tubing to other compressed air components; A valve is controlled by a handle that can be moved into several positions.
W	**Work**	The result of a force moving against a resistance; The act of compressing air is an example of doing work.

LEGO® Element Survey



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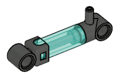

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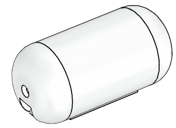

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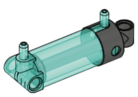

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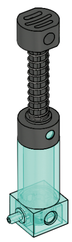

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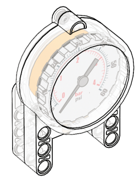

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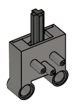

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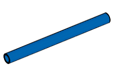

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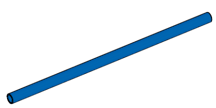

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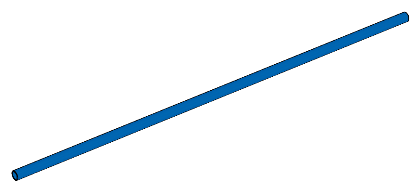

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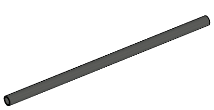

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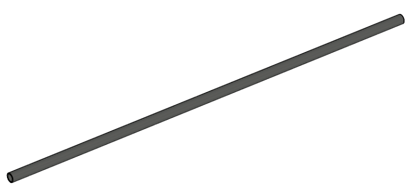

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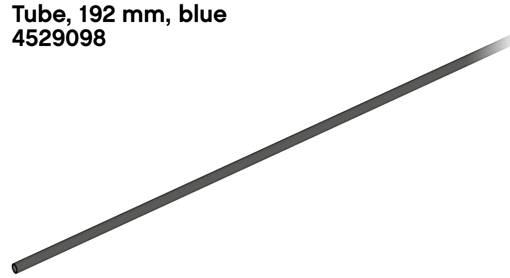

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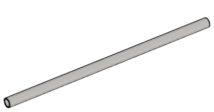

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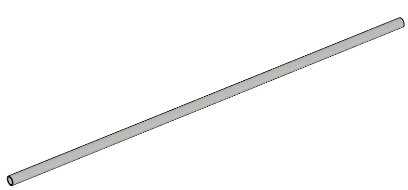

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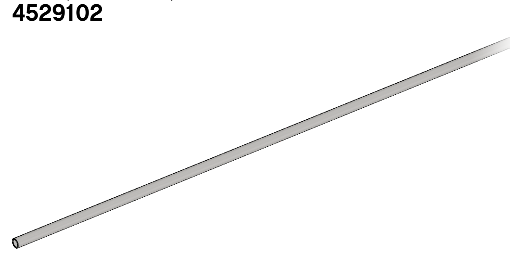

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Tube, 320 mm, grey
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The machines shown in the video sequences are
kindly provided by:
Scissor Lift – Haulotte
Robot Hand – Aarhus Technical School
Stamping Press – Bramidan
Robot Arm – Sealing System A/S