EXPERIMENT MANUAL

SIMPLE MACHINES

THAMES & KOSMOS

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››› IMPORTANT INFORMATION

››› **Warning!** Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Strangulation hazard — long cords may become wrapped around the neck.

››› Keep the packaging and instructions as they contain important information.

››› Store the experiment material and assembled models out of the reach of small children.

Dear Parents,

Physics is an exciting and varied science that is not hard to understand, especially when you use fun models to demonstrate physics principles in action. It can be a lot of fun to figure out the astonishing physical phenomena that we encounter every day and to put this understanding to use.

This experiment kit and the working models you can build with it introduce your child to physics concepts including forces, work, mechanical advantage — and of course simple machines. With its wealth of simple examples, your child will gain basic insights into the world of physical units and laws — which will help him or her to understand and engage more deeply in the lessons taught in school.

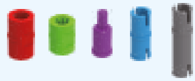
The individual experimental models are assembled step by step using an adjustable building system. It will require a little practice and patience at first. And your child will be particularly happy to have your help with the models that he or she finds more difficult.

Some of the experiments will require a helping hand or some water to fill the bottle to be used as a weight. Please help your child each step of the way.

We wish you and your child lots of fun experimenting, discovering, and learning!

TIPS

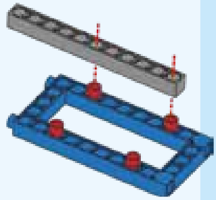
ANCHOR PINS AND CONNECTORS



Take a careful look at the different assembly components. Red anchor pins, green anchor pins, joint pins, and shaft plugs all look pretty similar at first glance. When you assemble the models, it's important to use the right ones. The green anchor pins are shorter than the red ones.

CONNECTING FRAMES AND RODS

Use the anchor pins to connect frames and rods.

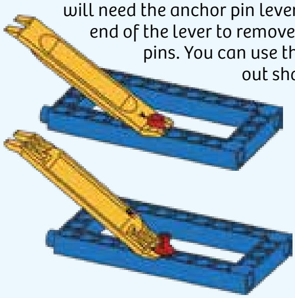


AXLES

The building system contains axles (also called shafts) of various lengths. When assembling the model, always be sure that you're using the right one.

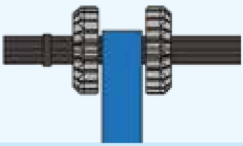
ANCHOR PIN LEVER

When you want to take your model apart again, you will need the anchor pin lever. Use the narrow end of the lever to remove the red anchor pins. You can use the wide end to pry out shaft plugs.



PULLEYS AND GEARS

If pulleys or gears are mounted too tightly against other components, they can be hard to turn. If you leave a gap of about 1 mm between the gear or pulley and an adjacent component, it will turn easily.



››› INTRODUCTION

Simple machines are devices that make physical work easier by changing the amount of force required to do work or changing the direction of the force required to do work. To understand this, we first need to understand what forces and work are.

For the purpose of this kit, you can think of a **force** as a push or a pull that causes an object to move, or change its speed if it is already moving. When you push on a door to open it, you are applying force to the door to move it open. Forces act on masses (objects with mass) in specific directions.

You may think of work as the chores your parents make you do or the assignments you do in school, but to a physicist, **work** is the amount of energy exerted when a force moves an object a certain distance. When you carry a box of toys up the stairs, you are doing work equal to the amount of force it takes to move that box the distance from the bottom of the stairs to the top.

Simple machines make work easier to do by allowing you to push or pull with less force or in a more convenient direction to move an object. But, any force that is saved by using a simple machine must be accounted for in terms of **distance.** This is an important rule to remember about simple machines. The amount a simple machine makes work easier is called its **mechanical advantage.** There are six classic types of simple machines:

Lever

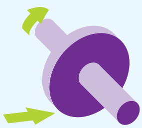
A lever is a rigid bar that can be pivoted on a point, called the fulcrum. Applying force to one part of the lever will cause a load (weight) somewhere else on the lever to move.

Inclined Plane

This is a ramp where one end is higher than the other. Moving an object up the ramp requires less force than lifting the object vertically.

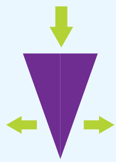
Wheel and Axle

This is a wheel with a pole through its center called the axle. It is actually a type of lever that rotates around the fulcrum. **Gears** are wheels with meshing teeth.



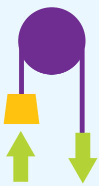
Wedge

A wedge is two inclined planes attached back to back. It converts a force acting on its end into two perpendicular forces acting out from the sides.



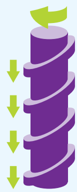
Pulley

A pulley is a wheel and axle with a groove in its circumference. A rope or chain is run through the groove. A weight attached to one end can be moved by pulling in the opposite direction on the other end.



Screw

A screw is an inclined plane wrapped around a pole. It converts are turning force into a straight (linear) force along the length of the pole.

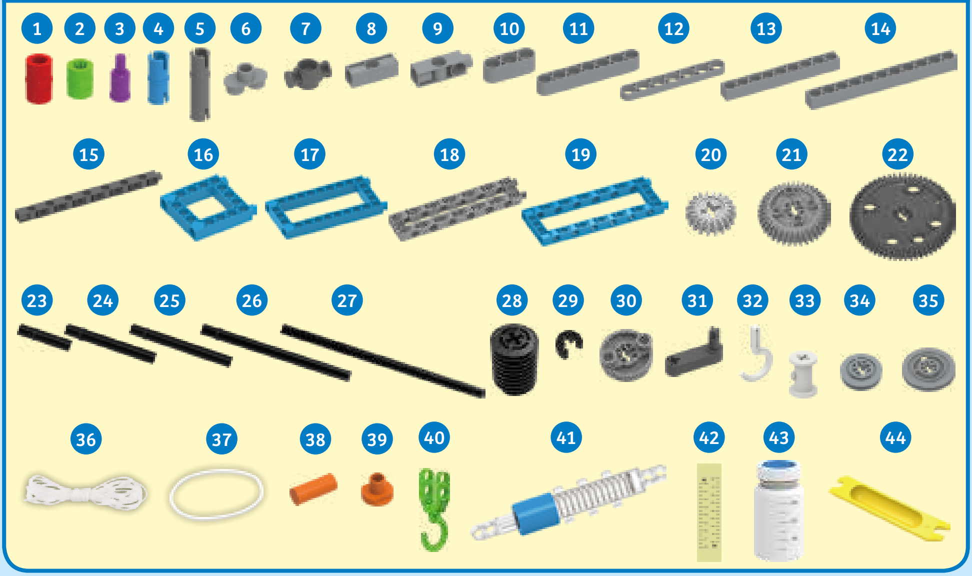


››› KIT CONTENTS

GOOD TO KNOW! If you are missing any parts, please contact Thames & Kosmos customer service.

US: techsupport@thamesandkosmos.com
UK: techsupport@thamesandkosmos.co.uk

What's inside your experiment kit:



Checklist: Find – Inspect – Check off

✔	No.	Description	Qty.	Item No.
◯	1	Anchor pin, red	30	7061-W86-R30
◯	2	Short anchor pin, green	20	7344-W86-C2G
◯	3	Shaft pin, purple	1	7413-W10-S1P
◯	4	Joint pin, blue	7	7413-W10-T1B
◯	5	Long joint pin, gray	2	7413-W10-U1S1
◯	6	Two-to-one converter	2	7061-W10-G1S2
◯	7	1-hole connector	2	7430-W10-B1S
◯	8	3-hole cross rod	2	7026-W10-X1S2
◯	9	3-hole dual rod	2	7413-W10-Y1S2
◯	10	3-hole wide rounded rod	4	7404-W10-C1S
◯	11	7-hole wide rounded rod	4	7404-W10-C2S
◯	12	7-hole flat rounded rod	4	7404-W10-C3S
◯	13	9-hole rod	2	7407-W10-C1S
◯	14	11-hole rod	2	7413-W10-P1S2
◯	15	15-hole dual rod	2	7413-W10-Z1S2
◯	16	Square frame	2	7413-W10-Q1B
◯	17	Large frame	2	7413-W10-I1B
◯	18	3x13 dual frame	2	7406-W10-A1S
◯	19	5x13 dual frame	2	7061-W10-U1B1
◯	20	Small gear	3	7026-W10-D2S
◯	21	Medium gear	2	7346-W10-C1S
◯	22	Large gear	2	7026-W10-W5S

✔	No.	Description	Qty.	Item No.
◯	23	35-mm axle	2	7413-W10-O1D
◯	24	60-mm axle	1	7413-W10-M1D
◯	25	70-mm axle	2	7061-W10-Q1D
◯	26	100-mm axle	1	7413-W10-L2D
◯	27	150-mm axle	2	7026-W10-P1D
◯	28	Worm gear	2	7344-W10-A1D
◯	29	Axle lock	2	3620-W10-A1D
◯	30	Rod-axle connector	2	7026-W10-L2S1
◯	31	Crank	1	7063-W10-B3S1
◯	32	Hook	1	7900-W10-H2SK
◯	33	Spool	1	7900-W10-H1SK
◯	34	Small pulley wheel	2	7344-W10-N3S2
◯	35	Medium pulley wheel	2	7344-W10-N2S2
◯	36	String, 200 cm	1	R39-W85-200
◯	37	Rubber band	1	R10-02
◯	38	Tube bolt	1	7404-W10-G1O
◯	39	Tube bolt cap	1	7404-W10-G2O
◯	40	Spring scale hook	2	7428-W10-A1G
◯	41	Spring scale	1	7428-W85-A
◯	42	Spring scale sticker	1	R20#7428
◯	43	Weight bottle	1	7428-W85-B
◯	44	Anchor pin lever	1	7061-W10-B1Y

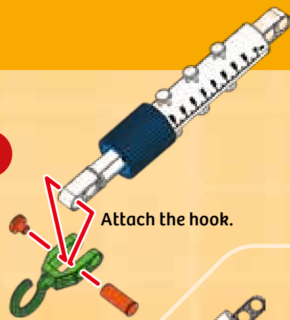
››› TABLE OF CONTENTS

An old-fashioned spring scale

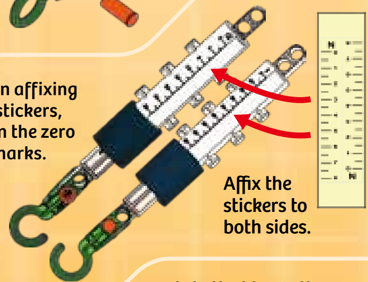
Measuring forces with the spring scale

In order to be able to experiment with simple machines and see what they are doing, we need a way to measure forces. To do this, we will use a **spring scale,** which is a simple tool that uses a metal spring to measure forces. The spring scale in this kit is specially designed to connect to the building system used in this kit (and other Thames & Kosmos kits).

The theory behind the way a spring scale works is that the amount of force it takes to stretch the spring is proportional to the distance the force stretches the spring. In other words, a large force will stretch the spring a lot and a small force will stretch the spring only a little. By measuring the distance a spring is stretched, we can approximate the force being exerted on the spring.

1 

Attach the hook.

2 

When affixing the stickers, align the zero (0) marks.

Affix the stickers to both sides.

3 

Done!

Rotate the blue collar to align the zero (0) on the scale to the force indicator disk at the top of the inner rod.

Test the Spring Scale

This spring scale measures forces in grams and Newtons, which is the standard unit of force in physics. Try weighing some objects from around your house to get a feel for how the spring scale works.

Do not hold the spring scale by the blue collar when taking measurements.

Do not measure weights of more than 800 grams.

Water Bottle Weight

In many of the experiments, you will need a weight to see how the simple machine is working. A 150-ml bottle is included. When filled with water, it acts as a weight — also called a **load**.

WORK

The amount of work you accomplish can be calculated as follows:

work [J] = force [N] • distance [m]

In the example with the bottle, let's take gravity as the force, and the distance is the difference in height when you lift the bottle.

work performed on the bottle [J] = mass [N] • local gravity [N/kg] • difference in height [m]

MECHANICAL ADVANTAGE

A machine makes work easier by multiplying the effort force applied to the machine. This multiplication factor is called the mechanical advantage (MA) of the machine. It is calculated as follows:

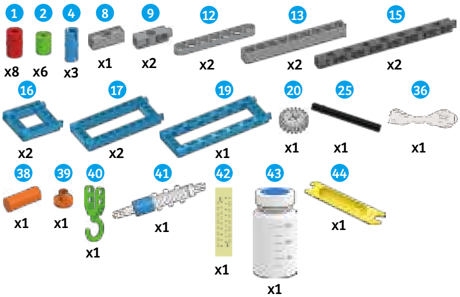
MA = load force / effort force

Divide the load force (also called the resistance force) by effort force to calculate the mechanical advantage. You can measure the forces with the spring scale.

EXPERIMENTS 1–3

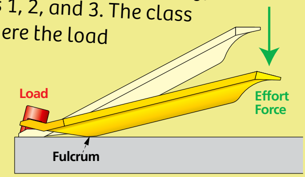
Three types of levers

YOU WILL NEED

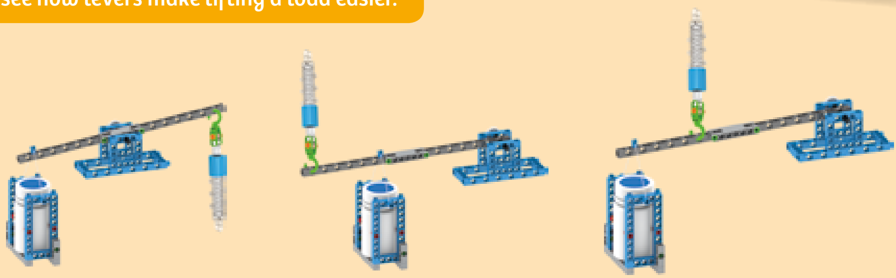


LEVERS

Levers are rigid bars that pivot on a point called the fulcrum. A weight (or load) at one point on the bar can be moved by applying a force (the effort) to another point on the bar. If the distance from the fulcrum to the effort (the effort arm) is greater than the distance from the fulcrum to the load (the load arm), then a smaller force can move a larger load. This is how the lever makes work easier. There are three types of levers: Class 1, 2, and 3. The class depends on where the load and force are positioned relative to the fulcrum.



Levers Section Objective: Experiment to see how levers make lifting a load easier.

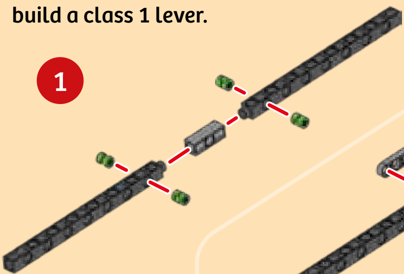


Class 1 Lever

HERE'S HOW

Follow steps 1 through 8 to build a class 1 lever.

1



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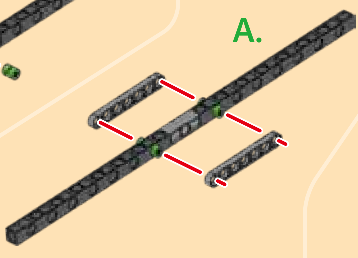

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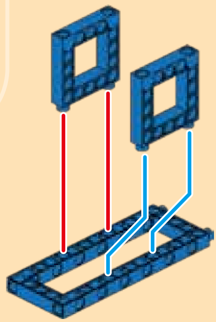
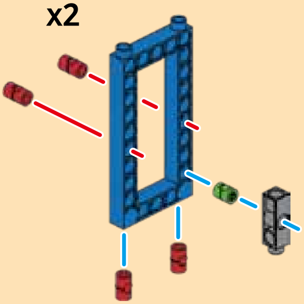


EXPERIMENT 1

4 **Note: x2 = build two of these**



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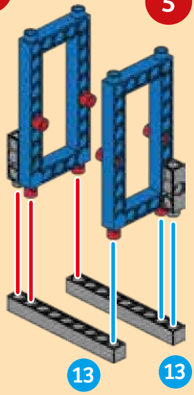

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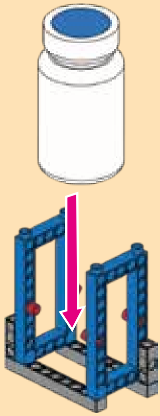

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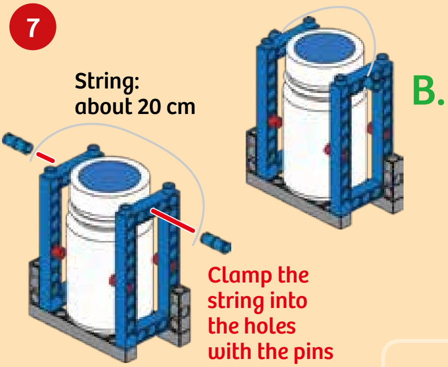

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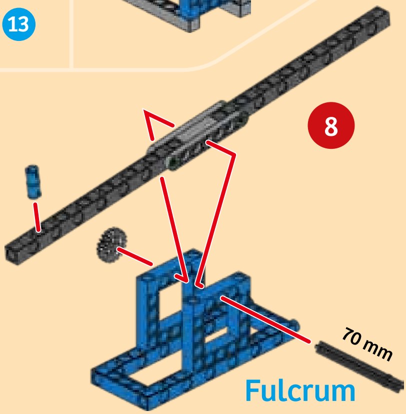
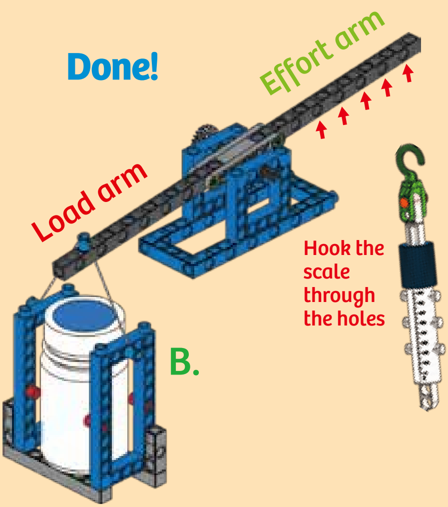
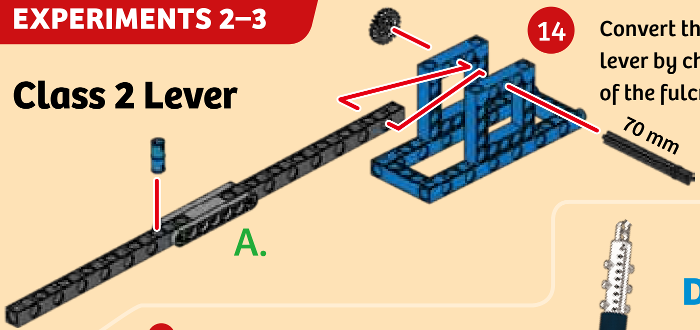




9. Fill the bottle with water and put the bottle in the basket. This is called the load.
10. Weigh the load with the spring scale. Adjust the amount of water until the bottle weighs 1 newton.
11. Position the model on the corner of a table. Have a helper hold the blue base of the model.
12. Hook the load over the joint pin on the load arm.
13. Hook the scale through each of the holes in the effort arm, starting with the outermost hole and working your way inward, and read the spring scale each time. What do you notice?

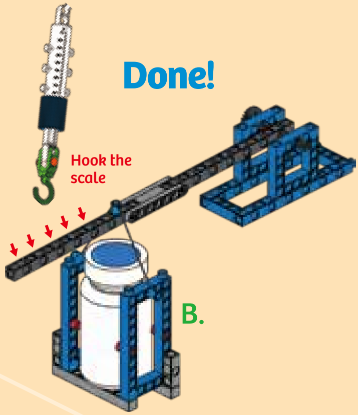
EXPERIMENTS 2–3

Class 2 Lever



14 Convert the model into a class 2 lever by changing the location of the fulcrum and joint pin.

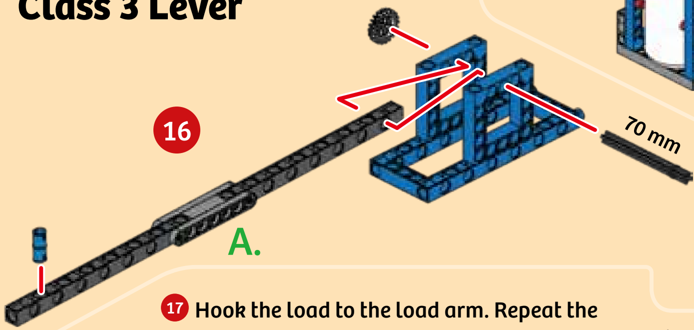
15 Hook the load to the load arm. Repeat the measurements with the spring scale. This time, the load arm and the effort arm are on the same side of the fulcrum. What do you observe?



Done!

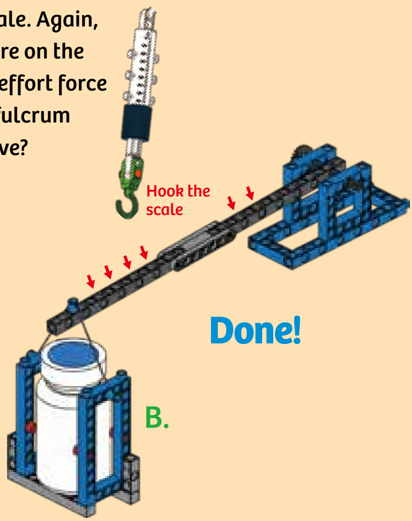
Class 3 Lever

16



Convert the model into a class 3 lever by changing the location of the joint pin.

17 Hook the load to the load arm. Repeat the measurements with the spring scale. Again, the load arm and the effort arm are on the same side of the fulcrum, but the effort force (the spring scale) is closer to the fulcrum than the load. What do you observe?



Done!

WHAT'S HAPPENING?

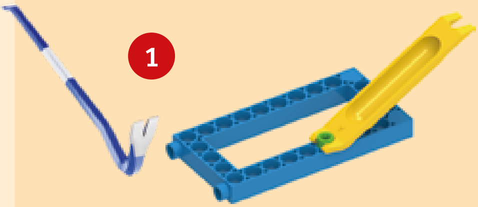
In the class 1 lever, a downward force on the load side is counteracted by a downward force on the effort side. In the other two levers, the load force is downward and the effort force is upward. In all three levers, you should see that the closer the spring scale hook is to the fulcrum, the more effort force it takes to lift the load.

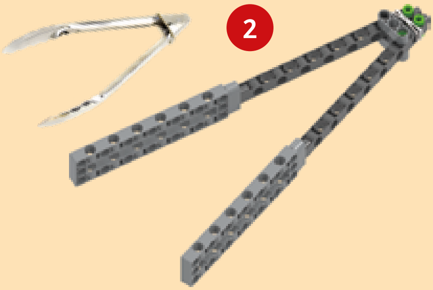
EXPERIMENTS 4–7

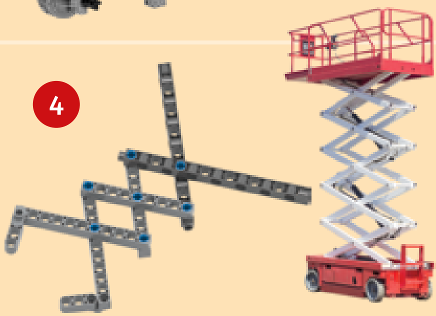
Levers, levers, and more levers

HERE'S HOW

Try building each of these four simple machines. They are all levers. Can you figure out what class of lever each one is? Answers below.







WHAT'S HAPPENING?

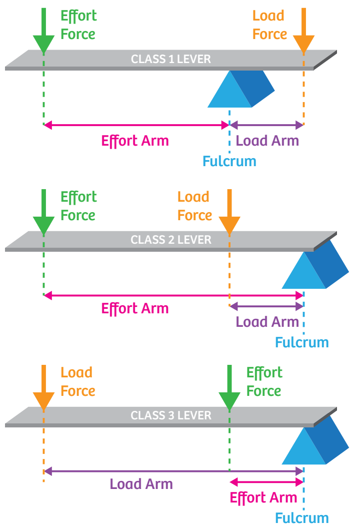
A lever amplifies an input force (the effort) to provide a greater output force at the load. The ratio of the output to input force is the **mechanical advantage (MA)** of the lever. This is also equal to the length of the Effort Lever Arm divided by the length of the Load Arm.

Effort Force • Effort Arm = Load Force • Load Arm

MA = Load Force / Effort Force

MA = Effort Arm / Load Arm

In the lever experiments, you can see how as the distance between the point of application of the effort force and the fulcrum decreases, the load feels heavier — the mechanical advantage decreases.



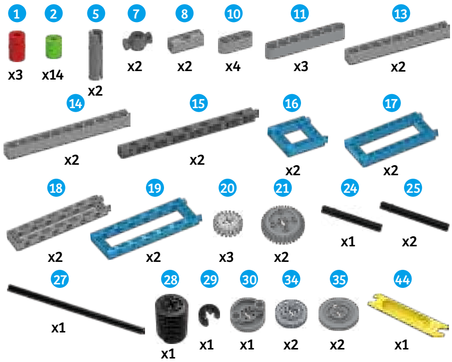
1. Class 1; 2. Class 3; 3. Class 2; 4. Multiple class 1 levers

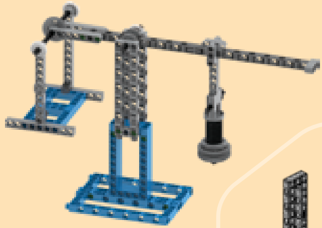
EXPERIMENT 8

Balance scale

DIFFICULT

YOU WILL NEED





HERE'S HOW

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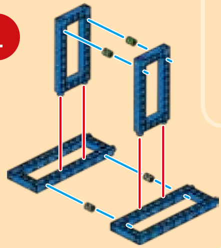

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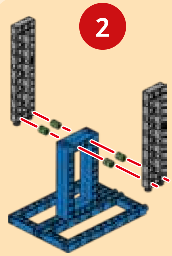

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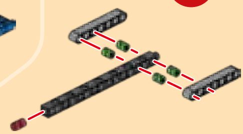

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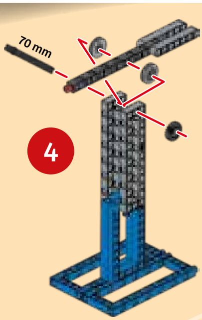

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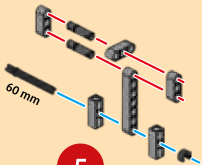

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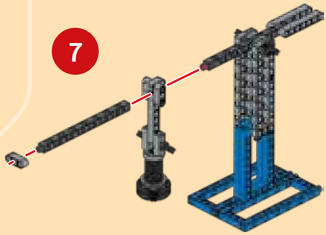

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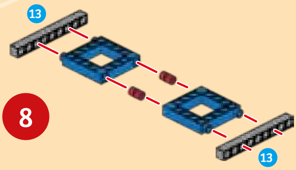

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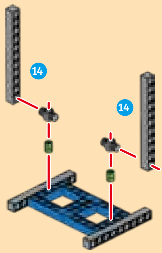

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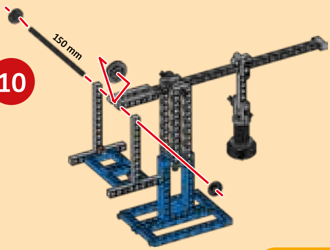


Done!

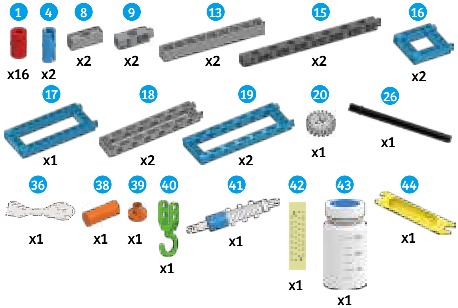
11 This balance scale is a class 1 lever. Try different loads in the basket and different locations of the weight on the other side.

Levers Section Conclusion: Levers make lifting loads easier. When you give up distance, you gain reduced effort force.

EXPERIMENT 9

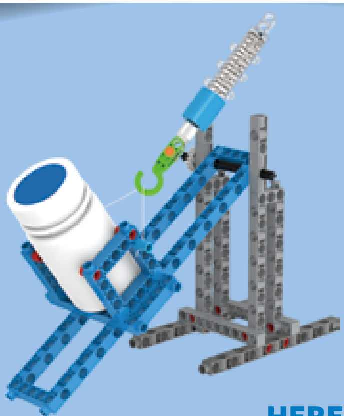
Ramp

YOU WILL NEED



INCLINED PLANES

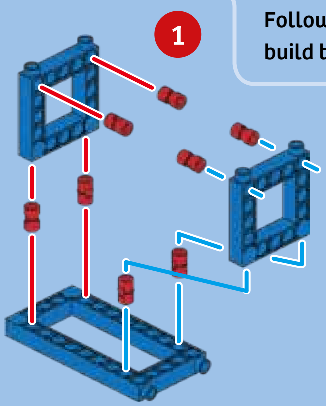
An inclined plane is a surface where one side is higher than the other. When an object is moved upward along an inclined plane, less force is needed than when the object is moved straight up the same vertical distance. The expense is that the object has to travel a longer distance when it moves up the ramp. The diagram below shows how forces act on an object on an inclined plane. The net force, the force required to move the object up the ramp, is less than the force of gravity, the force required to lift the object straight up in the air.

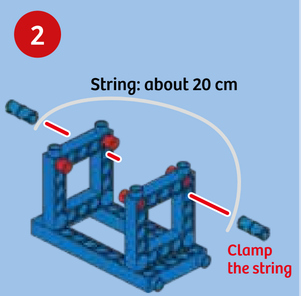


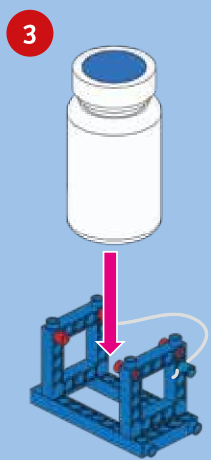
Inclined Planes Section Objective: With the levers, you saw how the effort force decreases when the effort arm distance increases. Now experiment to see how inclined planes reduce effort forces.

HERE'S HOW

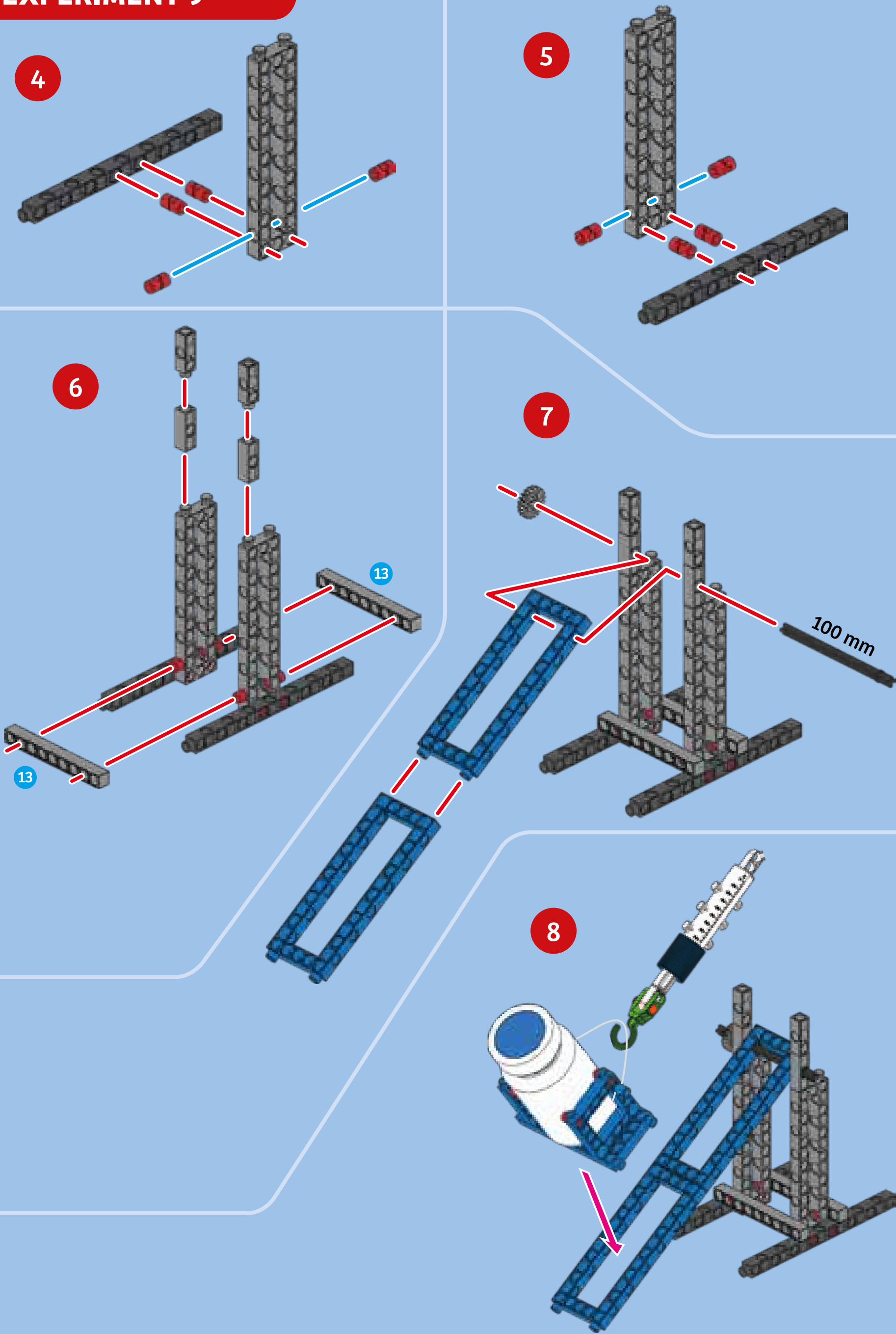
Follow steps 1 through 8 to build the ramp model.







EXPERIMENT 9



EXPERIMENT 9

9. As in Experiment 1, fill the bottle with water so the bottle and basket (the load) weigh 1 newton.

10. Hook the spring scale to the load and drag the load up the ramp with the spring scale, watching the scale as you do this. How does the ramp affect the amount of force needed to lift the load?

11. Fill the bottle with denser materials like sand, pebbles, or metal hardware and try lifting different weights on the ramp. What do you notice?

WHAT'S HAPPENING?

The ramp reduces the effort force required to lift the load.

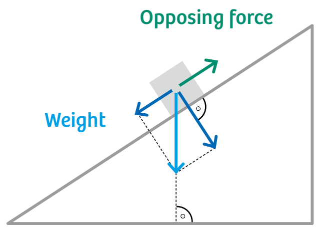
The weight is distributed across the inclined plane. A portion of the weight acts to make the block of stone slide down the ramp, but a portion of it also presses it against the ramp.

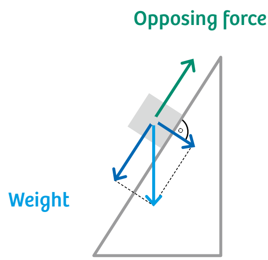
By setting a more or less equal opposing force against the portion of the force that would make the stone slide down the ramp, you can stop the stone or even pull it up. The steeper the ramp, the greater this portion of force. With a vertical "ramp," it is equal to the original weight of the block of stone.

Here, too, the distance covered on the ramp is longer than the actual difference in height, so it saves force. Remember:

work [j] = force [N] • distance [m]

With the model and the force meter from the first section, you can investigate this a little more closely.



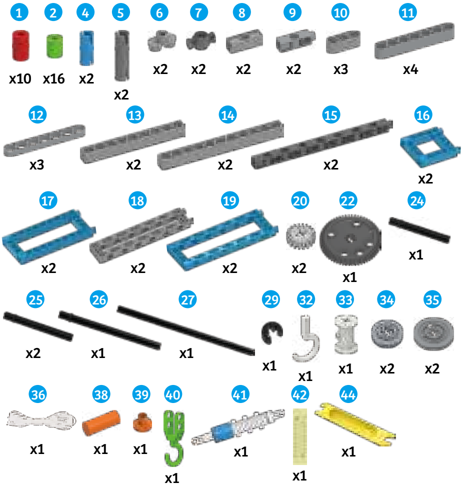


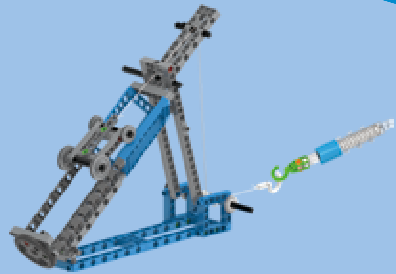
EXPERIMENT 10

Adjustable inclined plane

DIFFICULT

YOU WILL NEED

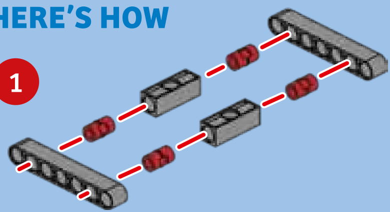




This model is a complex machine consisting of pulleys, wheels, and an inclined plane. You can easily adjust the angle of the ramp for experiments.

HERE'S HOW

1



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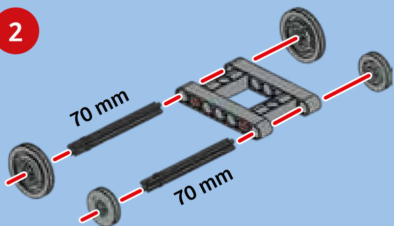

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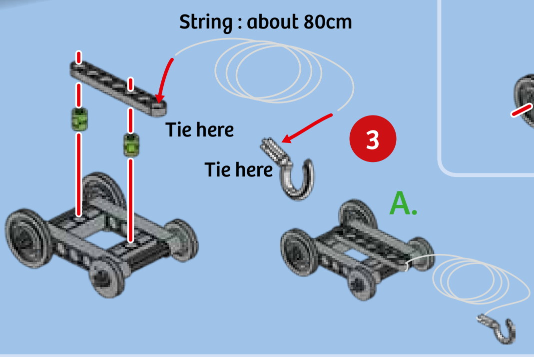

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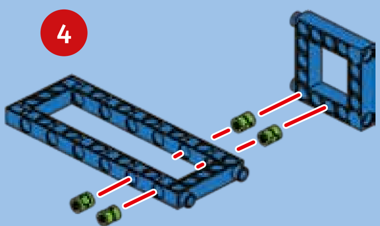

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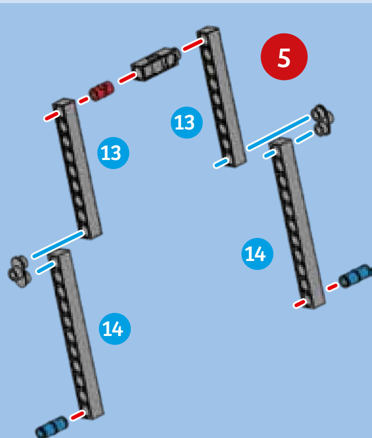
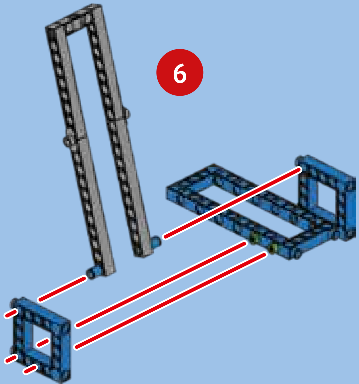


EXPERIMENT 10

6



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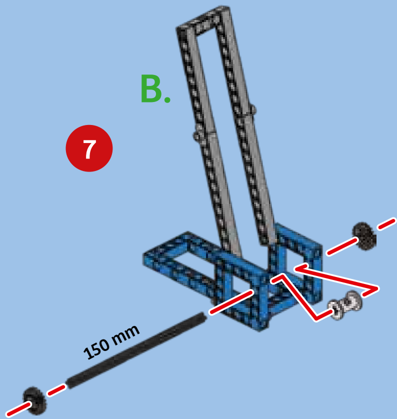

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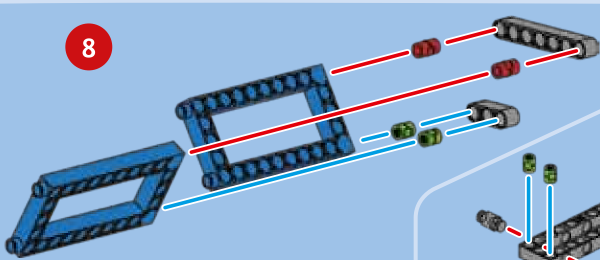

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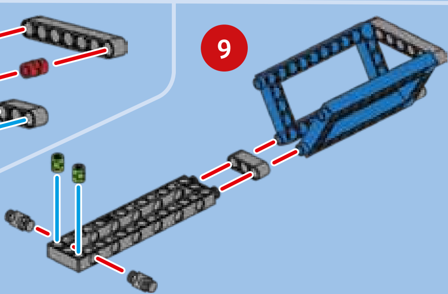

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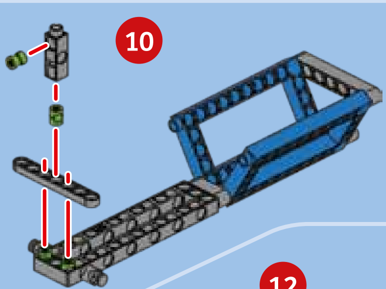

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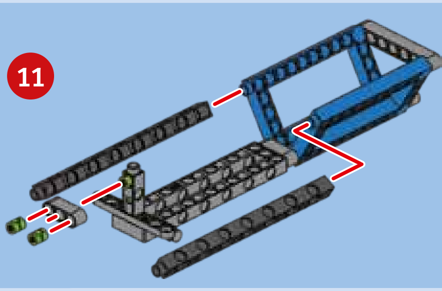

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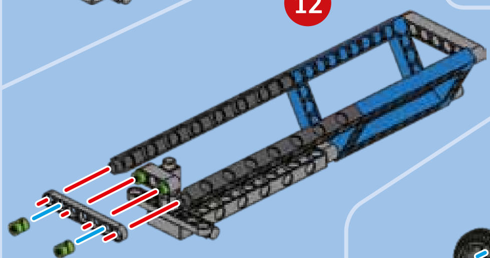

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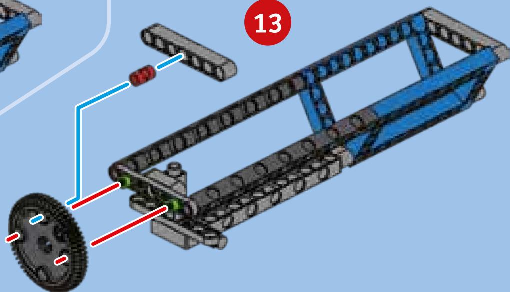
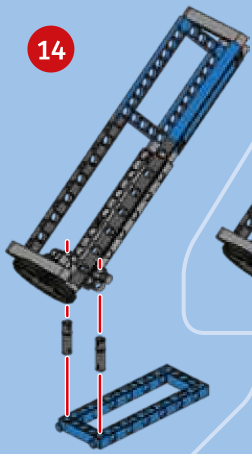


EXPERIMENT 10

14



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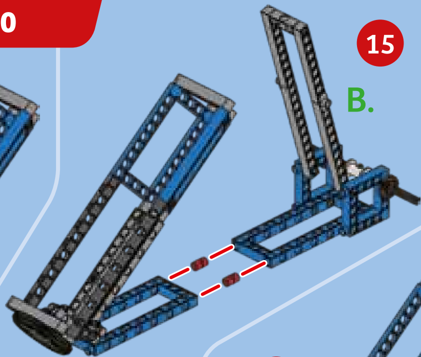

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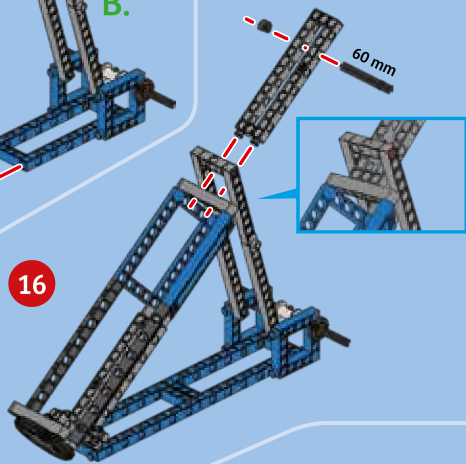

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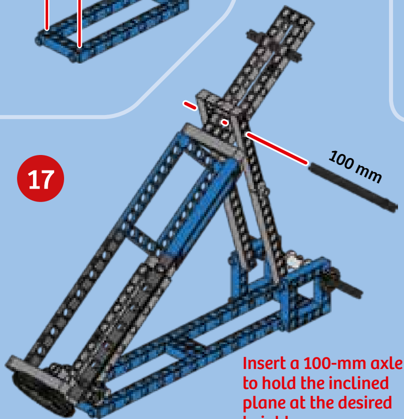

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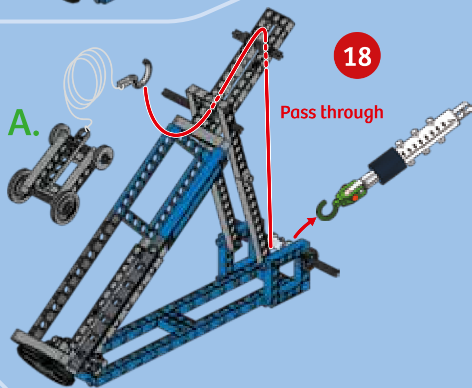
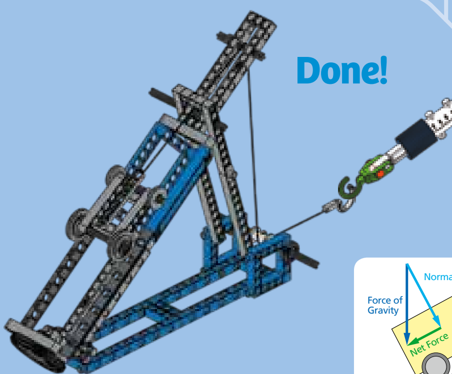
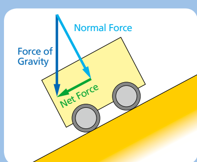






19 Position the ramp at the highest setting (the steepest angle).

20 Pull the car up the ramp with the string running over the pulleys. How much force does it take?

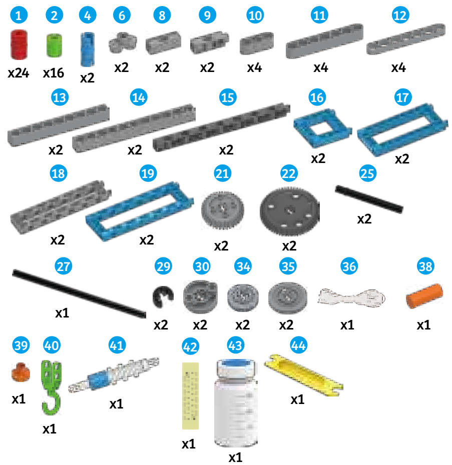
21 Position the ramp at the lowest setting and repeat the experiment. Now how much force does it take?

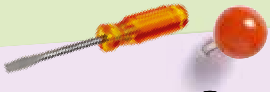
Inclined Planes Section Conclusion: An inclined plane reduces the amount of effort force required to lift a load, but this requires lifting the load over a longer distance.

EXPERIMENTS 11–12

Wheel and axle tests

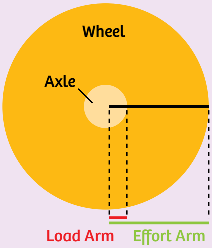
YOU WILL NEED





WHEELS AND AXLES

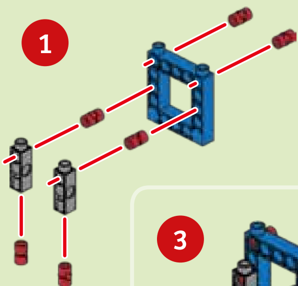
A wheel and axle together form a simple machine that is basically just a lever rotated around a center axis, or fulcrum. In this case, the force arm is the distance from the fulcrum to the edge of the wheel, while the load arm is the distance from the fulcrum to the edge of the axle. A small force applied to the edge of the wheel will result in a large force at the edge of the axle. Alternatively, a slow turning of the axle will yield a faster turning of the outer edge of the wheel, if speed is what you are after.

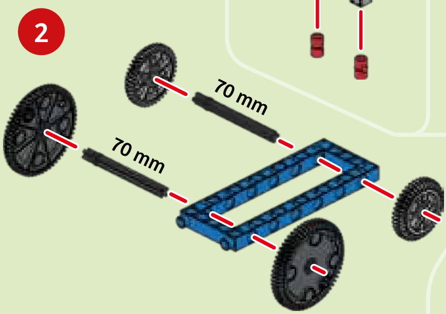


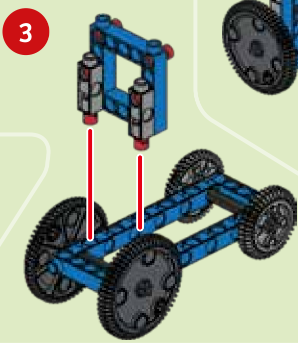
Wheels and Axles Section Objective: Experiment to see how wheels and axles affect the effort force needed to move loads.

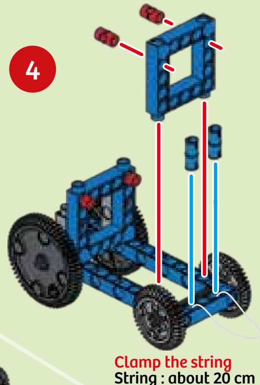
HERE'S HOW

Follow steps 1 through 5 to build a simple car with four wheels and two axles.



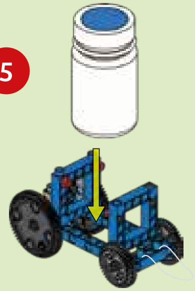






EXPERIMENT 11

5

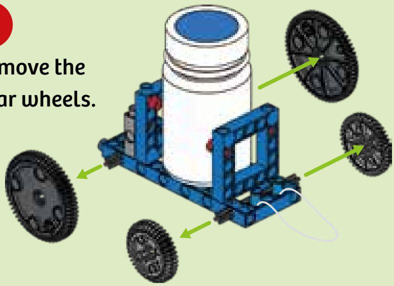


Done!

6 Fill the bottle with water.

7 Hook the spring scale to the loop of string on the model. Drag the model across the table by the spring scale. Note the effort force.

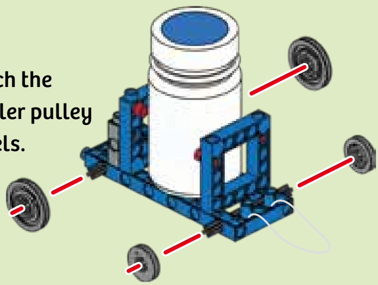
8 Remove the gear wheels.



Done!

9 Repeat the experiment, this time dragging the car chassis without any wheels attached to it across the table. Note the effort force this time.

10 Attach the smaller pulley wheels.



Done!

11 Repeat the experiment again with the smaller wheels and note the effort force.

How do the wheels affect the amount of force it takes to move the load?

WHAT'S HAPPENING?

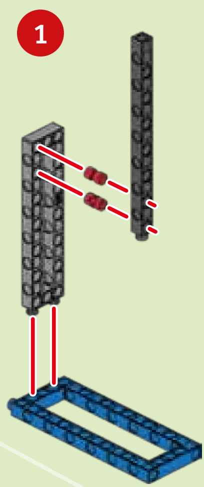
The wheels reduce the amount of effort force required to move the load across the table. Pulling the chassis without wheels requires the most amount of effort force. This is largely because of something called friction. The greatest cause of work in everyday life is friction. Friction is a force that works against the direction of movement of an object (which is why it always gives rise to work in terms of physics). Friction occurs when two surfaces touch. Even on seemingly smooth surfaces, there are lots of uneven spots that look like canyons and mountains under a powerful microscope. When two surfaces meet, these microscopic uneven spots will catch on one another and push against each other. That is the cause of friction.

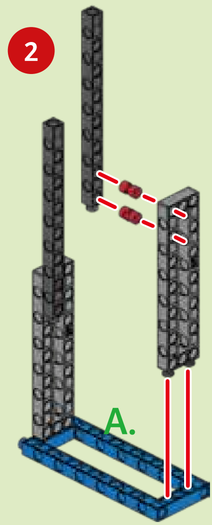
EXPERIMENT 12

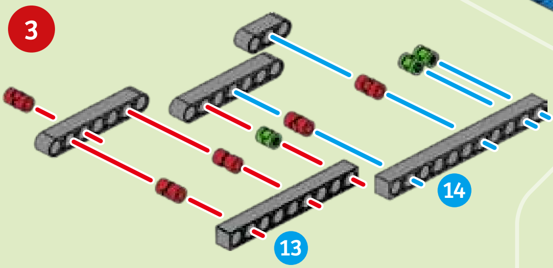
Wheels and axles on an inclined plane

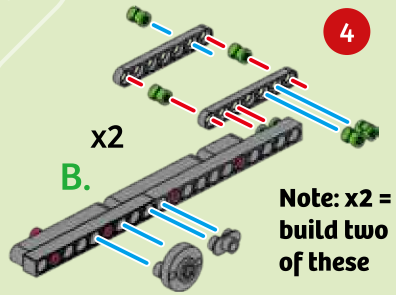
HERE'S HOW

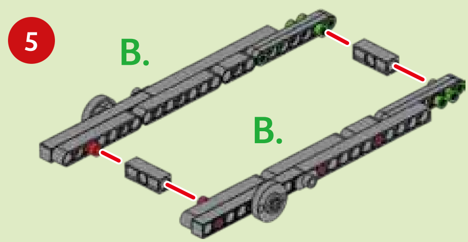
Follow steps 1 through 7 to build an inclined plane for the car to drive up.

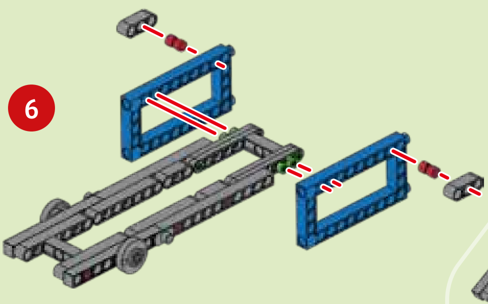


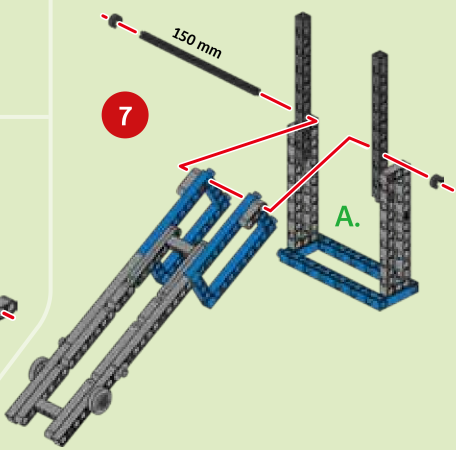










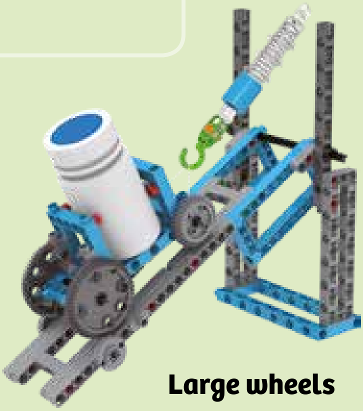


EXPERIMENT 12

Done!

Small wheels

8. Place the car with the smaller wheels from Experiment 12 on the ramp.
9. Hook the spring scale to the loop of string on the car. Drag the model up the ramp by the spring scale. Note the effort force. Compare this to the effort force required to move the car across the flat table.



Large wheels

10. Remove the small wheels and reattach the larger wheels to the car.
11. Repeat the experiment of pulling the car up the ramp with the spring scale. Note the results and compare them to your previous findings.

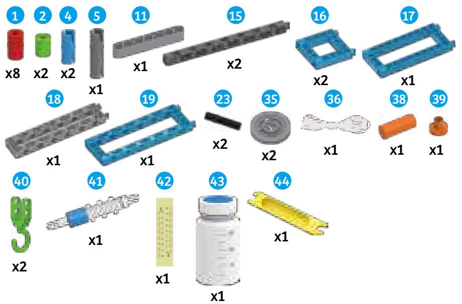
WHAT'S HAPPENING?

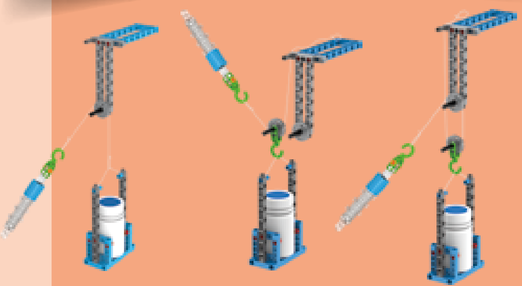
The combination of the wheels with the inclined plane result in a machine that requires less effort force to lift the load. Because of the limited precision of the spring scale, you may find it difficult to tell the difference between the effect of the larger gear wheels and the smaller pulley wheels. The spring scale may indicate very little force at all — this shows you how effective wheels and axles are as simple machines. The larger wheels should require less force than the smaller wheels. The larger the wheel, the longer the effort lever arm, and therefore the less effort force is needed. The smaller the wheel, the more effort force is needed.

Wheels and Axles Section Conclusion: Wheels and axles are like levers rotated around a central axis. The larger the wheel, the longer the effort force lever arm, and the higher the mechanical advantage. They also reduce friction.

Three types of pulleys

YOU WILL NEED





Pulleys Section Objective: Experiment to see how pulleys work like wheels and axles to reduce effort forces.

PULLEYS

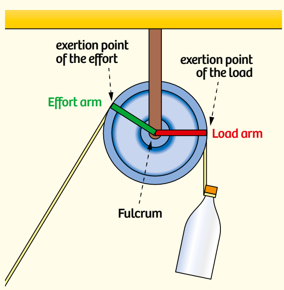
Pulleys are wheels and axles with ropes or chains running over them. There are three types of pulleys: fixed, movable, and compound.

A fixed pulley is an equal-armed, two-sided lever that rotates around a fulcrum. The force and load arms are equal in length, so it does not actually reduce the amount of force needed to move the load, but it does change the direction of the force, allowing the user to pull in a more convenient direction.

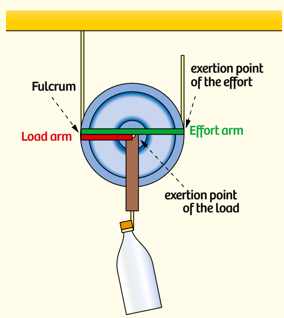
A movable pulley reduces the amount of force needed to lift the load, but at the cost of increasing the distance over which the rope has to move. The suspended load is divided between two ropes, cutting the force in half but doubling the distance.

A compound pulley is a combination of a fixed and a movable pulley. This allows for both a convenient pulling direction as well as a reduction in the amount of force needed to lift the load. Many compound pulleys can be put together in a row to make a device called a block and tackle, which increases the mechanical advantage.

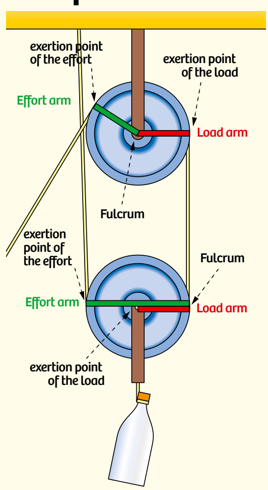
Fixed



Movable



Compound

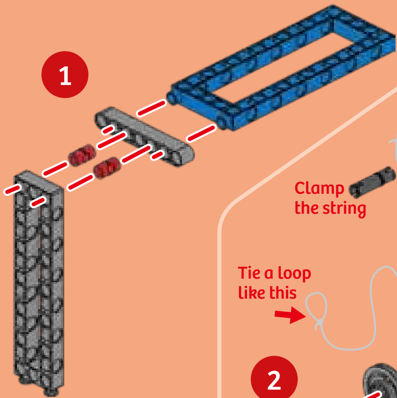


EXPERIMENTS 13–15

HERE'S HOW

Follow steps 1 through 7 to build the components of the three pulley models.

1



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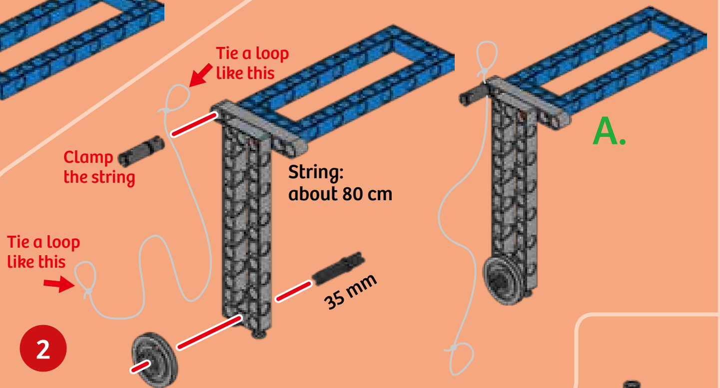

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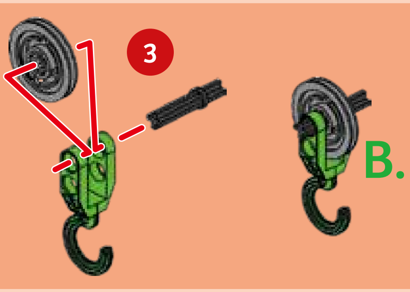
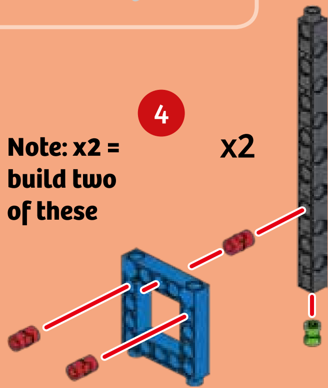


4

Note: x2 = build two of these



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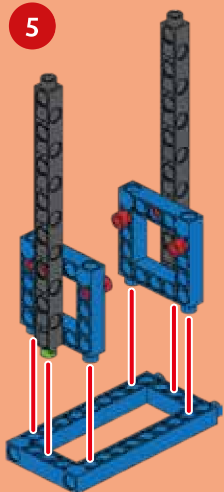

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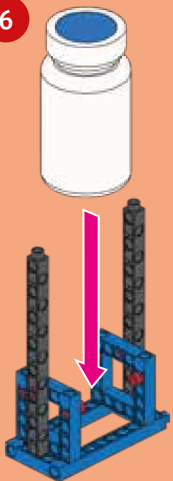

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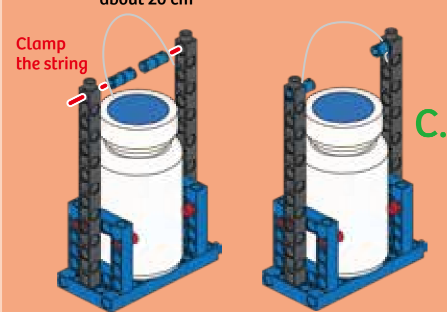
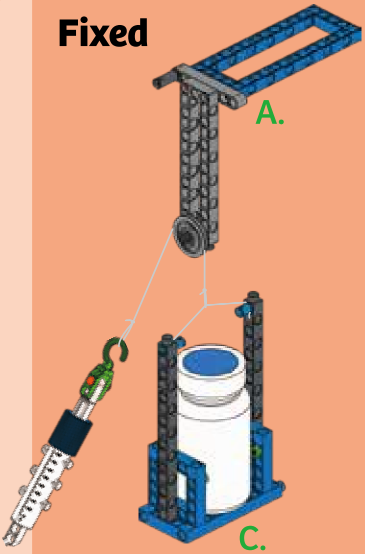
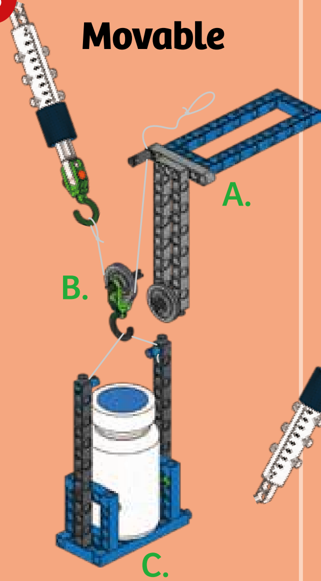


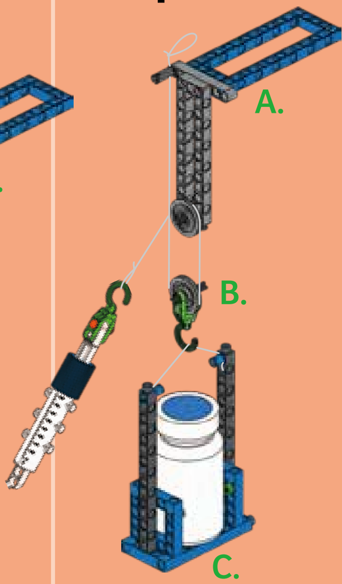
Fixed



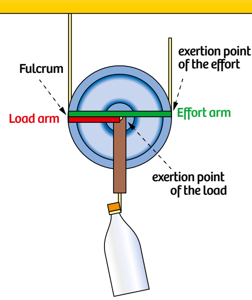
Movable



Compound



8. Fill the bottle with water so that the bottle and basket together (the load) weigh 1 newton.
9. Assemble components A and C together as shown. Have a helper hold the blue 5x13 dual frame on the edge of a table.
10. Measure the effort force required to lift the load with the spring scale.
11. Reconfigure the setup into a movable pulley as shown.
12. Lift the load again with the spring scale and measure the effort force.
13. Reconfigure the setup into a compound pulley as shown.
14. Lift the load again with the spring scale and measure the force.



WHAT'S HAPPENING?

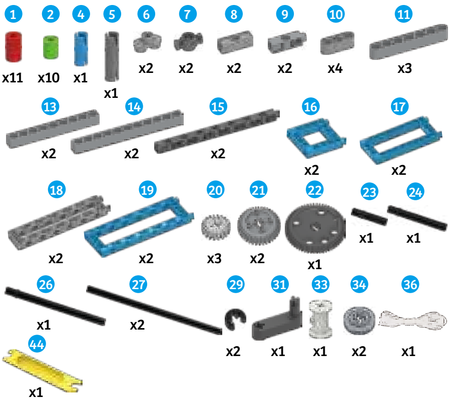
The fixed pulley is a two-armed lever that rotates around a fulcrum as it does work. Its load arm and lever arm are equally long, so the user does not gain a mechanical advantage. However, this pulley is useful because it changes the direction in which force is applied. In the movable pulley the effort arm is twice as long as the load arm, so the effort force is reduced to only half the load force. In the compound pulley, you get the convenient downward pulling direction of the fixed pulley combined with the mechanical advantage of the movable pulley.

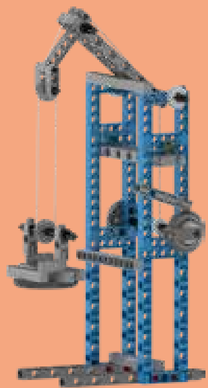
EXPERIMENT 16

Elevator with pulleys

DIFFICULT

YOU WILL NEED

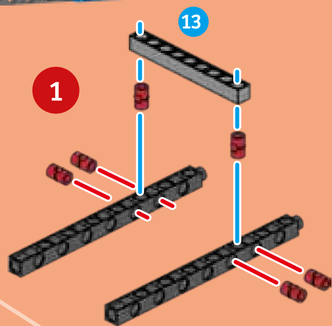




HERE'S HOW

Follow steps 1 through 16 to build an elevator model that lifts a carriage with a pulley system.

1



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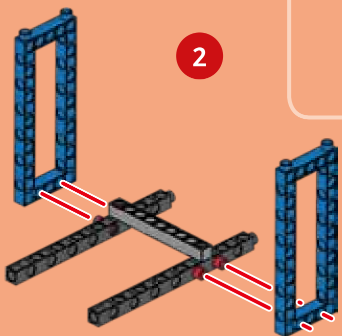
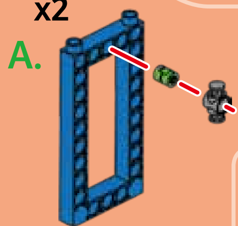


3

x2



Note: x2 = build two of these

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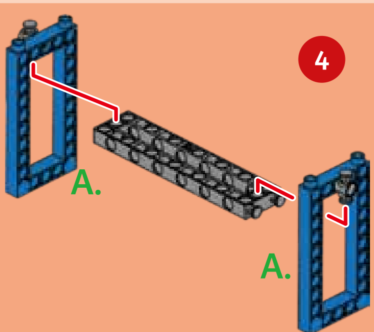

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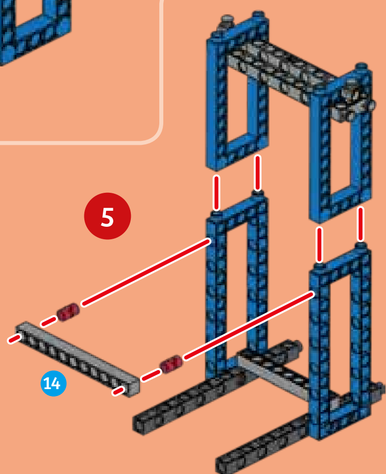

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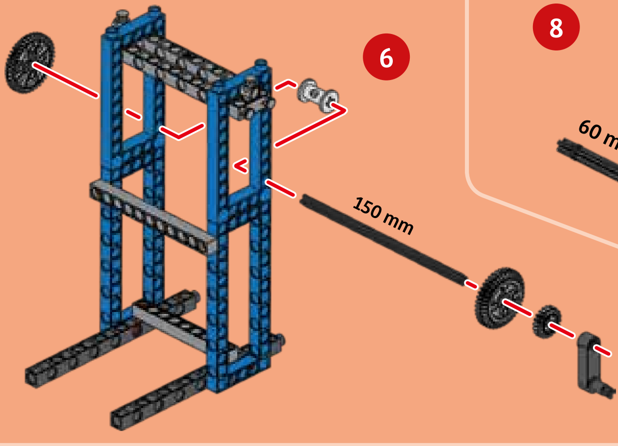

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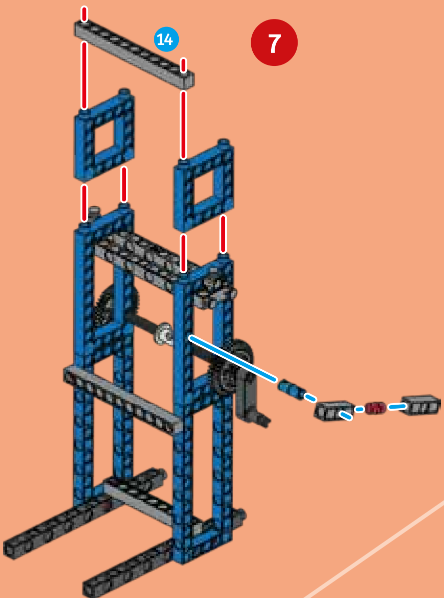

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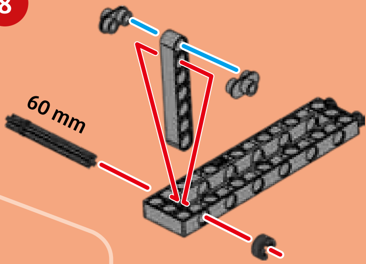

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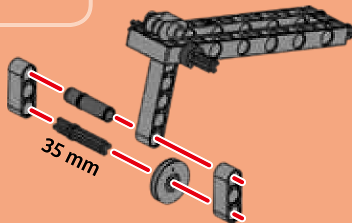

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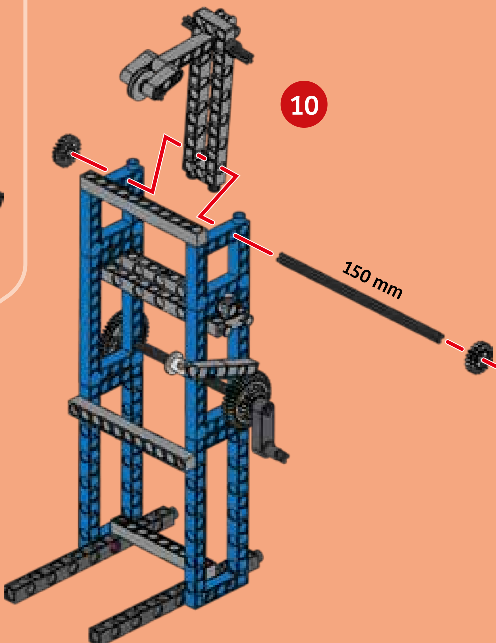
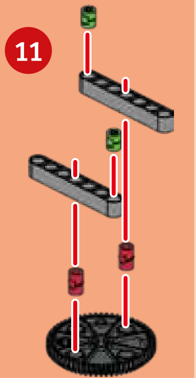
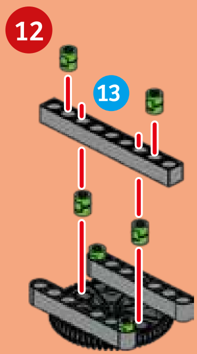
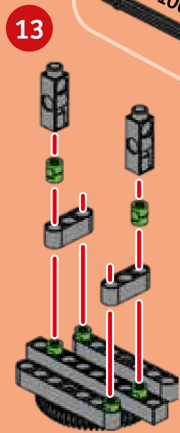
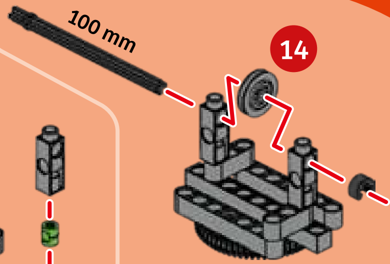


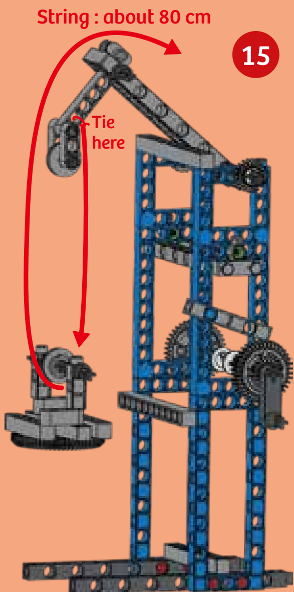
EXPERIMENT 16

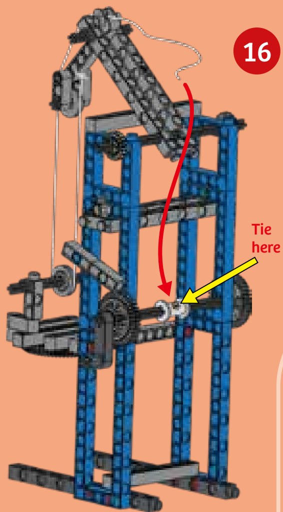


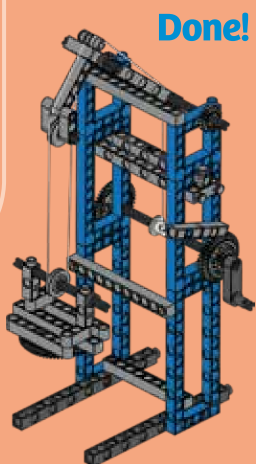












17 Turn the crank to lift the carriage. A device called a ratchet allows the crank to turn in only one direction, preventing the carriage from falling down when you remove your hand from the crank.

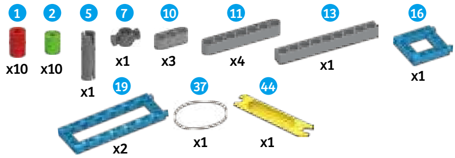
How many simple machines can you spot in this model?

Pulleys Section Conclusion: A pulley is a wheel and axle with a rope or chain running over the wheel. Pulleys can be used to change the direction of a force and reduce the effort force needed to lift a load.

EXPERIMENTS 17–18

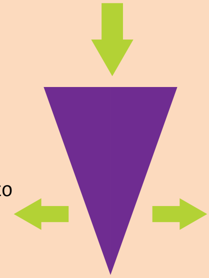
Wedges

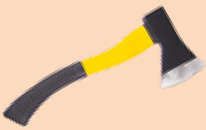
YOU WILL NEED

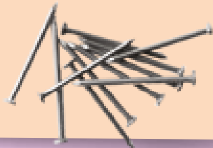


WEDGES

A wedge is made when two inclined planes are attached back to back. The wedge converts force applied to its blunt side into two outward forces from its longer sides.

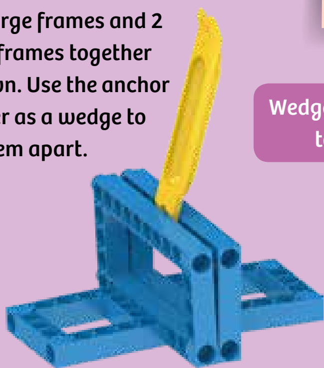




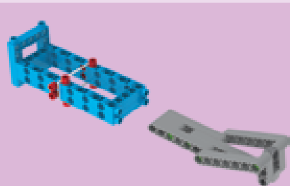


HERE'S HOW

1 Put 2 large frames and 2 square frames together as shown. Use the anchor pin lever as a wedge to split them apart.

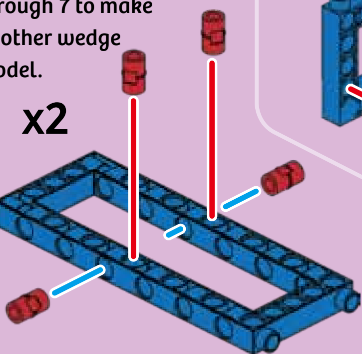


Wedges Section Objective: Experiment with wedges to see how they work like inclined planes.



2 Now follow steps 2 through 7 to make another wedge model.

x2



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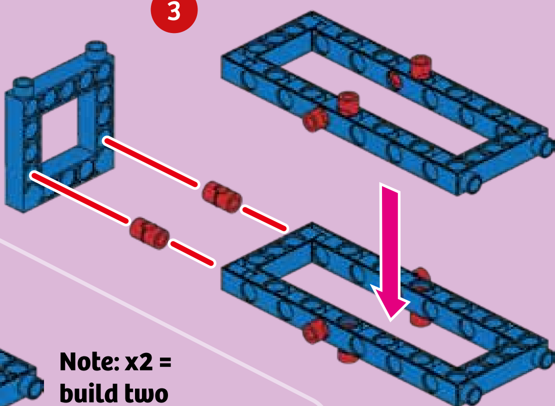
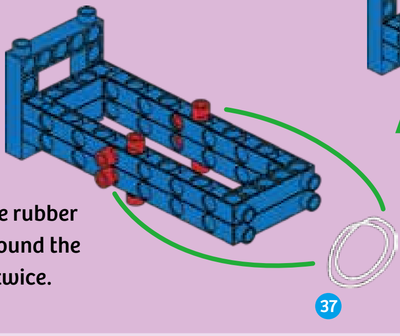


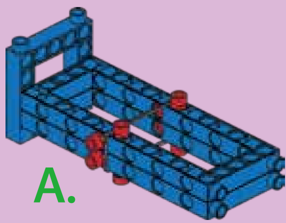
Note: x2 = build two of these

EXPERIMENTS 17–18

4



Wrap the rubber band around the frames twice.



A.

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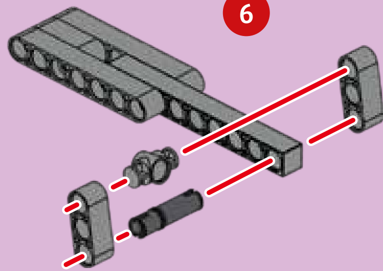

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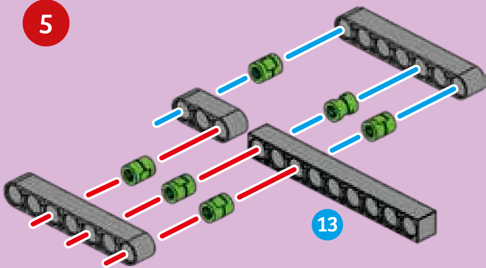

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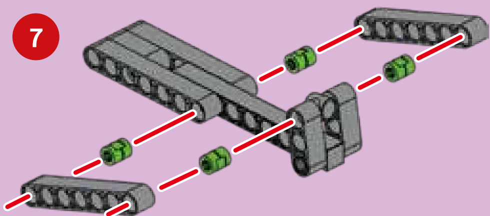
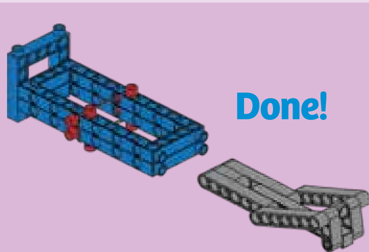




Done!

8 Slide the wedge into the test device made from the blue frames. Is separating the two frames easier using the wedge?

WHAT'S HAPPENING?

The wedges make it easier to separate the frames in your experiments. A wedge works like two inclined planes stuck to each other. A wedge can also be thought of as a portable inclined plane. When a wedge is inserted between two surfaces, and you apply force to the wedge's blunt end, it transfers those forces outward, perpendicularly from its inclined (or angled) faces to those surfaces. The mechanical advantage of a wedge is proportional to the ratio between its length and width. But, just like with an inclined plane, to achieve a lower effort force, you must use a longer wedge: You have to give a great distance to get a lower effort force.

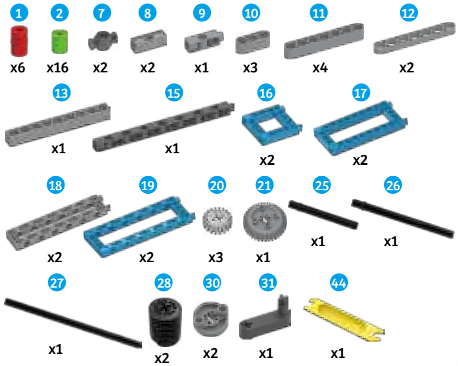
Wedges Section Conclusion: A wedge reduces effort force by distributing the force over a greater distance.

EXPERIMENT 19

Workbench vise with screw

DIFFICULT

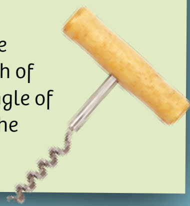
YOU WILL NEED

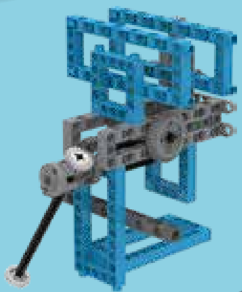


SCREWS

A screw is an inclined plane wrapped around a cylinder. When a screw is turned, the turning force is converted into a linear force along the length of the screw. A metal woodworking screw makes it easier to bore itself into a block of wood because with each rotation of the screw, the threads move a lot farther than the tip of the screw that is being driven into the wood. Again, the force is reduced but the distance is increased.

The mechanical advantage of a screw depends on the pitch of the threads. The pitch is the angle of the inclined plane relative to the cylinder.

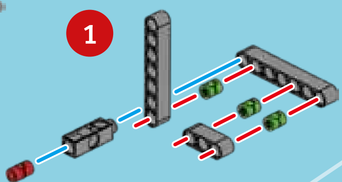


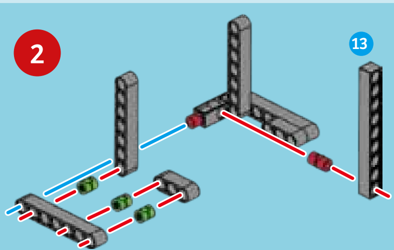


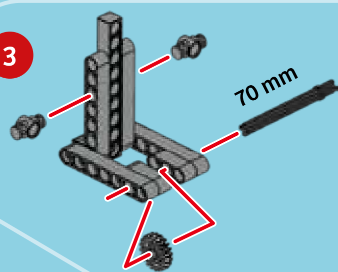
Screws Section Objective: Experiment with screws to see how they work like inclined planes.

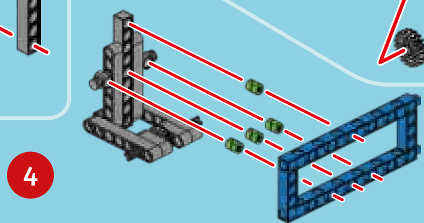
HERE'S HOW

Follow assembly steps 1 through 11 to build a workbench vise device that demonstrates the mechanical advantage of a screw.



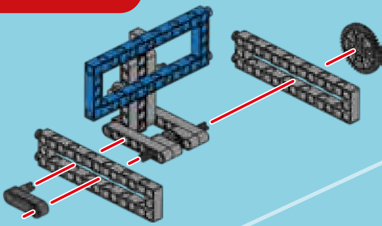






EXPERIMENT 19

5



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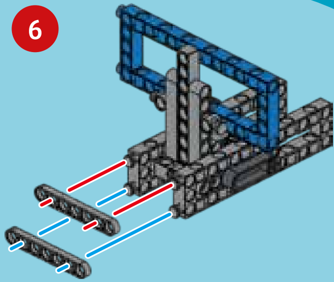

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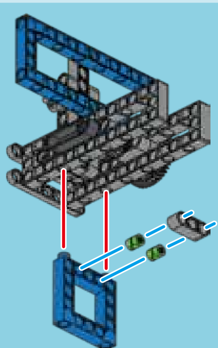

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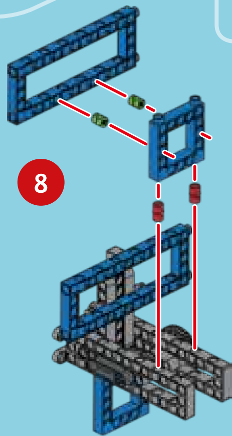

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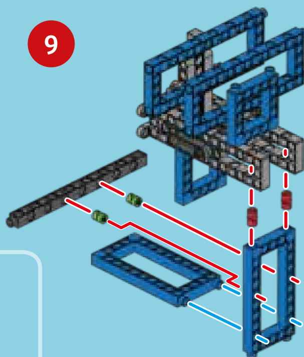

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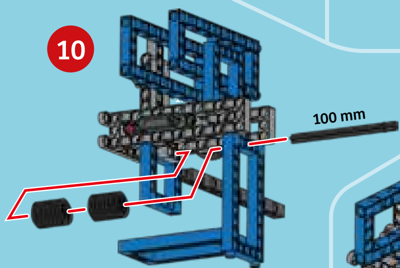

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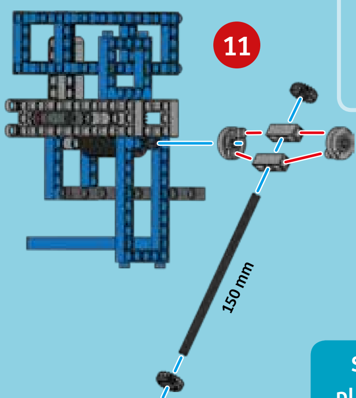
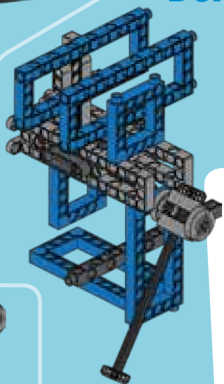


Done!



12 Place an object, like a foam ball or wad of paper towels, in the vise.

13 Slowly turn the screw to tighten the vise around the object.

WHAT'S HAPPENING?

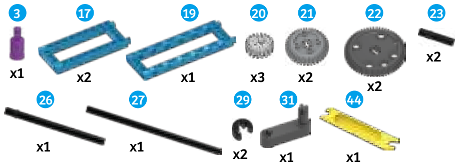
The screw allows you to apply a lot of force to squeeze the object in the vise while reducing the effort force. However, the distance you have to turn the screw is quite long, as indicated by the fact that it takes so long to tighten the vise.

Screws Section Conclusion: A screw is an inclined plane wrapped around a cylinder that reduces effort force by distributing force over a greater distance.

EXPERIMENT 20–25

Gears and transmissions

YOU WILL NEED



Gears Section Objective: Experiment with gears to see how they work like connected wheels and axles.

GEARS

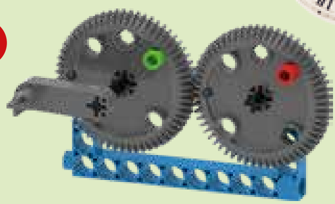
Gears are not considered one of the six classic simple machines, but they are often included in lists with the simple machines because they are so widely used. Gears are actually versions of wheels and axles with teeth that allow them to mesh together and turn each other.

The mechanical advantage of a gear is evident when a large gear meshes with a small gear. One full turn of the large gear will produce, say, three full turns of the small gear. Because of this, the smaller gear always turns faster than the larger. On the other hand, the larger gear turns with greater force than the smaller. So, in this way, gears can be used to make slow turning motion into rapid turning motion, or to covert small forces into large forces. Multiple gears meshing with each other are called gear trains, or transmissions.

HERE'S HOW

Build each of the 5 models shown. For each model, turn the crank and observe to determine 1) how many times the driven gears are turned by the driver gear (the cranked gear), and 2) the direction each gear turns.

1



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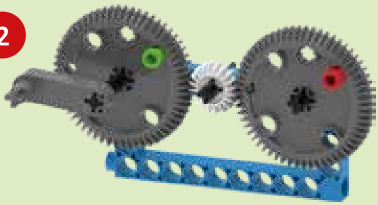

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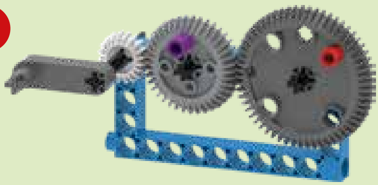

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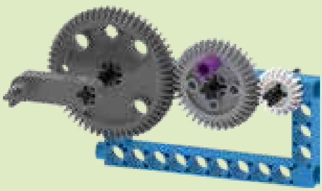

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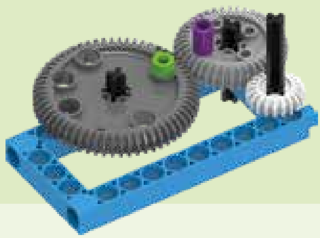
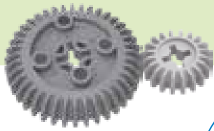
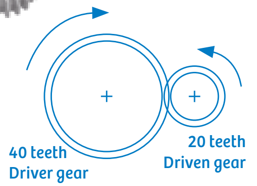


EXPERIMENT 20–25



WHAT'S HAPPENING?

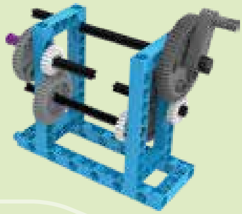
You built a series of gear trains. The gear connected to the crank (or any input force) is called the driver gear. The gear that is turned by the driver gear is called the driven gear. Gears of different sizes are used to increase or decrease the speed or the force of rotary motion, called torque. The relationship between the number of teeth on meshing gears is called the gear ratio. The gear ratio indicates the change in speed or torque from one gear to the other.



$$\text{Velocity ratio} = \frac{\text{Number teeth driven gear}}{\text{Number teeth driver gear}}$$

$$= \frac{20}{40} = \frac{1}{2} \quad (1:2)$$

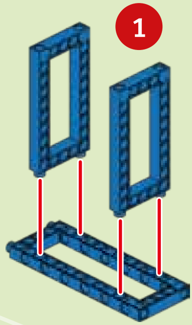
Transmission



HERE'S HOW

Follow steps 1 through 3 to build a geared transmission model.

1



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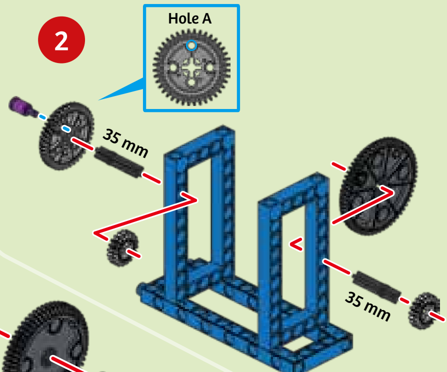
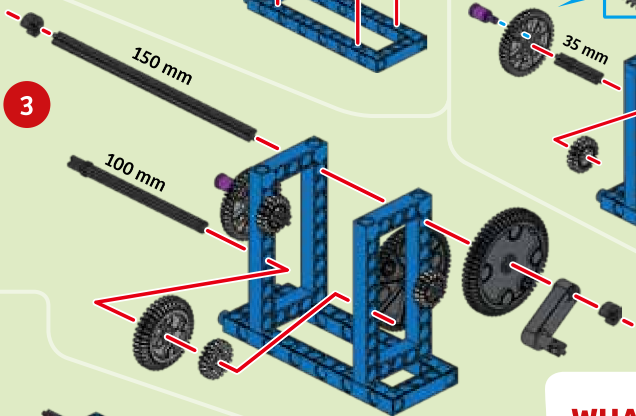
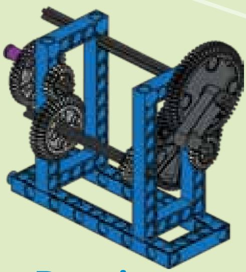


3





Done!

4 Turn the crank and watch the purple pin. How fast does it move?

5 Try turning the gear with the pin and watching the crank. What do you notice?

WHAT'S HAPPENING?

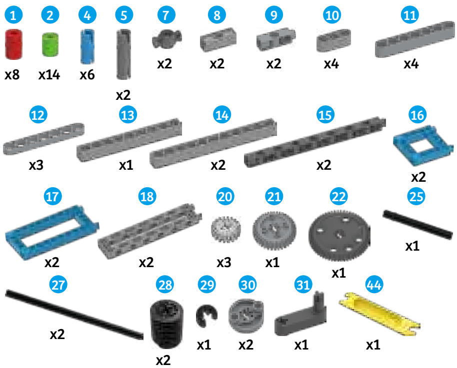
The three pairs of meshing gears in this model all increase the speed of the driven gears. When you combine them all together, you get a total increase in speed of eight times the original speed. In reverse, you get an increase in torque at the end driven gear.

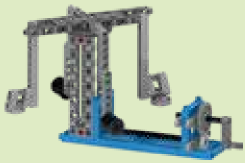
EXPERIMENT 26

Geared carousel

DIFFICULT

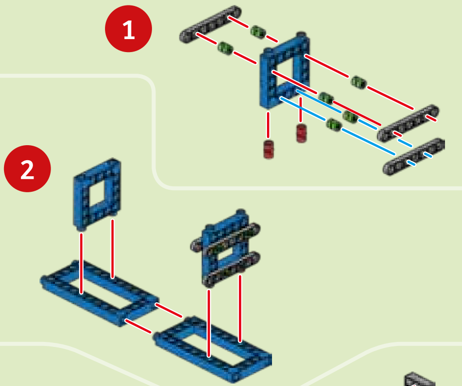
YOU WILL NEED

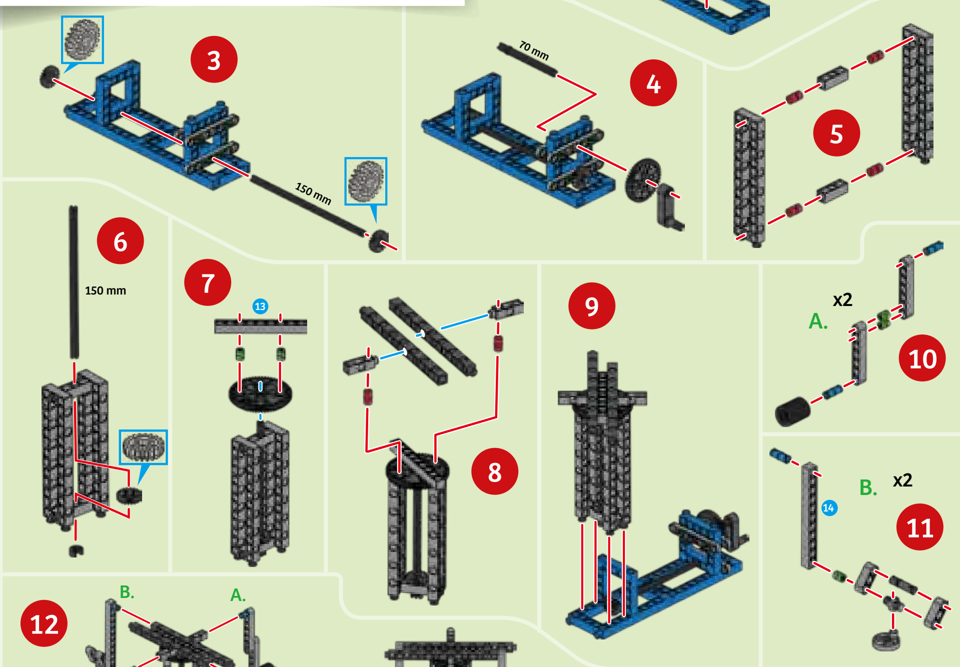


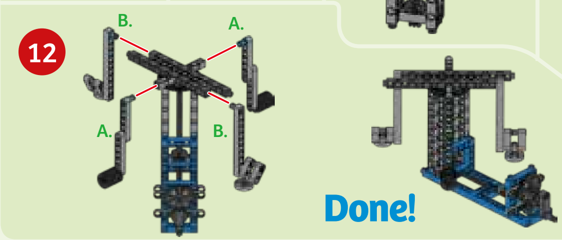


This fun model uses gears to spin a carousel, and also demonstrates rotational forces in action.

HERE'S HOW







Done!

Gears Section Conclusion: Gears are toothed wheels that can increase or decrease the speed or the torque of the output axle.

CORRELATES TO NGSS STANDARDS

The following NGSS Disciplinary Core Ideas and Performance Expectations most closely relate to the models and experiments in this kit.

Disciplinary Core Ideas

PS2 Motion and Stability: Forces and Interactions
PS3 Energy
ETS1 Engineering Design

Performance Expectations

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.

MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Technical product development: Genius Toy Taiwan Co., Ltd., Taichung, Taiwan, R.O.C. and Thames & Kosmos
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