



TECHNIC 101

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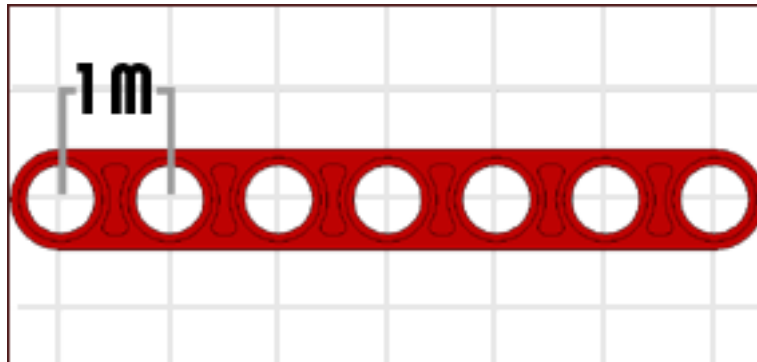
Giant cranes...huge earth-moving construction vehicles... offroad 4x4s... how do they make them? And how do they make them work?

That's what **LEGO TECHNIC** is all about! TECHNIC is an incredible building system that lets you combine gears, beams, wheels and other parts to build functional and amazingly realistic feats of engineering. TECHNIC creations can move, lift, rotate and spin, just like the real thing!

These lessons will provide basic tips to start you on your way to becoming a TECHNIC Master Builder. Along the way, we'll show you how to build working components that you can use in your own models. What you learn here can even be used in the world outside of LEGO building!

Getting to Know LEGO TECHNIC

TECHNIC building uses the "module" or "M" as a measurement of length. 1 M is the distance from the center of one hole on a TECHNIC beam to the center of the next hole.



TECHNIC includes many different parts, but most of them fit into 4 basic categories:

- Beams
- Connectors
- Gears
- Shape elements

Let's start with the basic parts:

BEAMS, PEGS AND AXLES

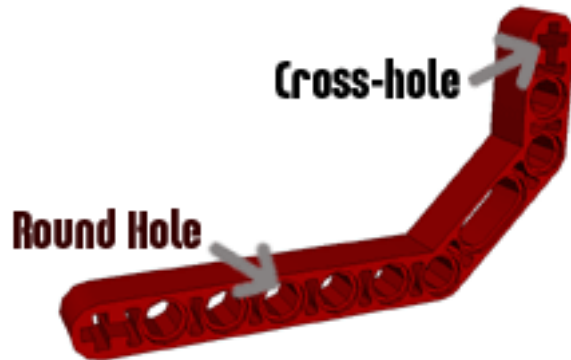
TECHNIC beams come in lengths from 2M all the way up to 15M. There are 4 types of angled beams as well.



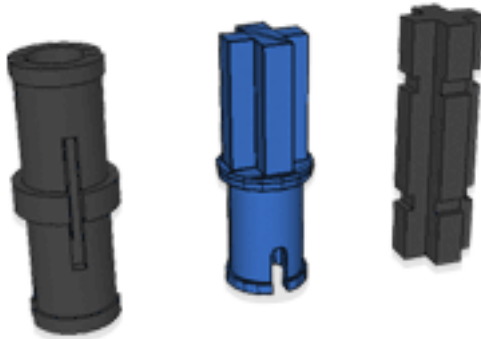
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There are 2 kinds of holes in TECHNIC pieces: round holes and cross-holes.



We use special pegs and cross-axes to attach TECHNIC parts together. They are shaped differently so that different types of connections can be built.



Cross-axes are color coded by length. Even-numbered lengths (2M, 4M, 6M, etc.) are black, and odd-numbered lengths (3M, 5M, etc.) are gray.

Now let's build a few simple connections!

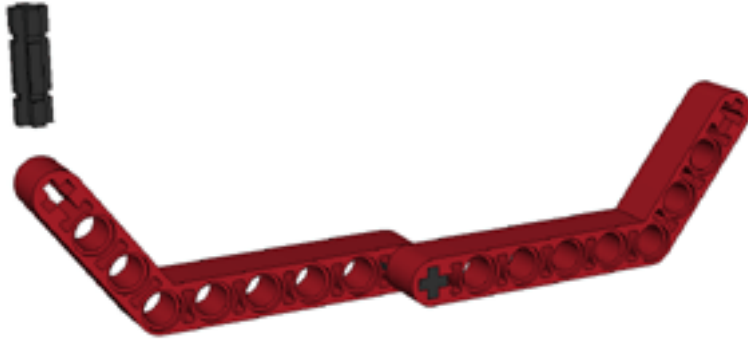




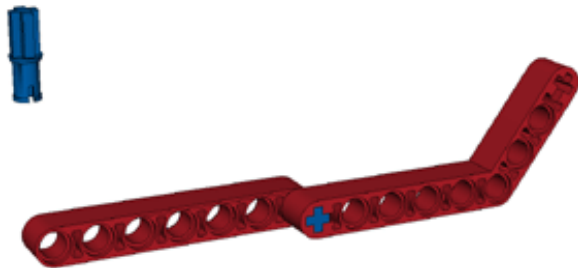
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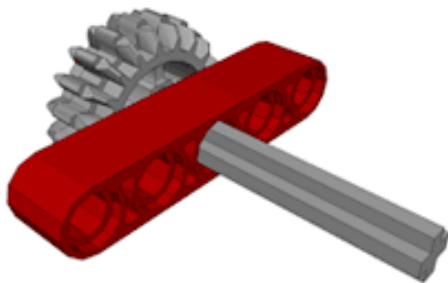
This connection uses a round peg to connect beams with round holes. The beams can be rotated at the point where they attach together.



This connection uses a cross-axle peg to connect beams with cross-holes. Cross-axle connections can lock beams at fixed right angles and keep them from spinning.



When connecting a beam with a crosshole to a beam with a round hole use this peg for a spinning connection.





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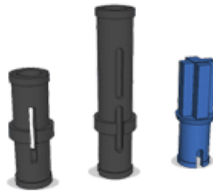
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You can also put a cross-axle through a round hole so it spins freely. This is a useful connection for building with wheels and gears.

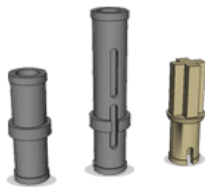
SMOOTH AND FRICTION PEGS

There are 2 kinds of pegs. Some are smooth and allow parts to spin freely. Others use friction to limit spinning. In newer TECHNIC sets, these pegs are color-coded to help you spot the difference easily.

Friction:



Smooth:



You can use smooth and friction pegs to control how fast and freely your TECHNIC parts rotate!

BASIC CONNECTORS



These are a few of the basic TECHNIC connectors. You can use pegs and cross-axes to connect them to beams for even more complex and realistic constructions!



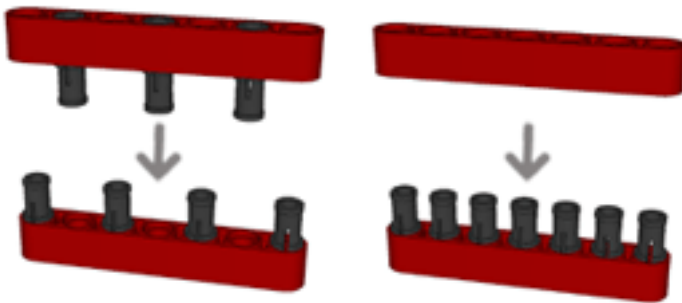
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MASTER BUILDER TIPS

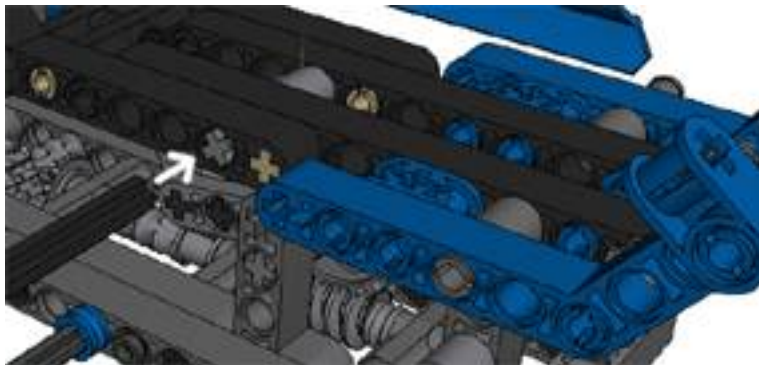
Here are a few tricks that the Master Builders use to make TECHNIC building easier!

Ever noticed that when you try to connect two beams using a lot of pegs, they don't always go together easily? Try building these two constructions:



Look how the second one is a lot harder to snap together! It's easier to line things up if you build your connections the first way.

Having trouble removing a peg or cross-axle? Use a long cross-axle part as a tool. Instead of pulling on the stuck peg or cross-axle, try pushing it out from the other side using your axle tool!





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Stability with LEGO TECHNIC

Learn how to add stability to your TECHNIC creations with statics, right triangles and even LEGO System elements!

Now that you've mastered the first stage of LEGO TECHNIC construction, let's look at the basic building principles that have helped to create some of the most amazing feats of engineering in the world.

STATICS

Before you can start on complex working machines, it's important to learn how to build a stable construction. "Statics" is the science of objects that aren't in motion. Engineers study statics so they can build bridges and buildings that will withstand huge forces. The same principles apply when building with LEGO TECHNIC. By applying these principles you'll be able to build so that your mechanical masterpiece won't fall apart as soon as the wheels start turning and the gears start spinning!

Let's start by building three quick connections.



Which of the three constructions is the strongest? Which is the weakest? Which will support the most force without bending or falling apart? From the examples above, the top connection is the strongest – because it uses two pins to connect with a 4M overlap. Remember, the more your beams overlap, the stronger your connection will be. For each part of your construction that you build, ask yourself: How strong does this connection need to be to support the functions of the construction?

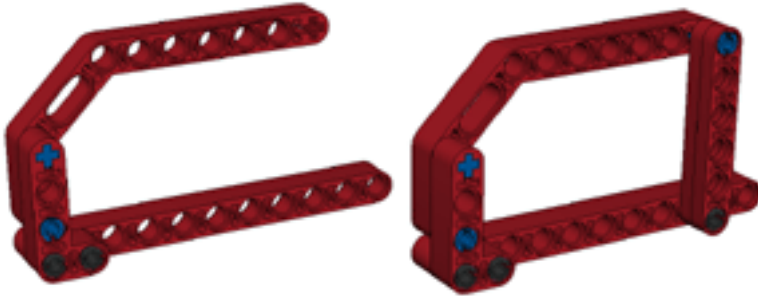
Another general rule for building strong TECHNIC structures is to close up open shapes. The first picture below will flex under stress because the open ends aren't supported by anything. The



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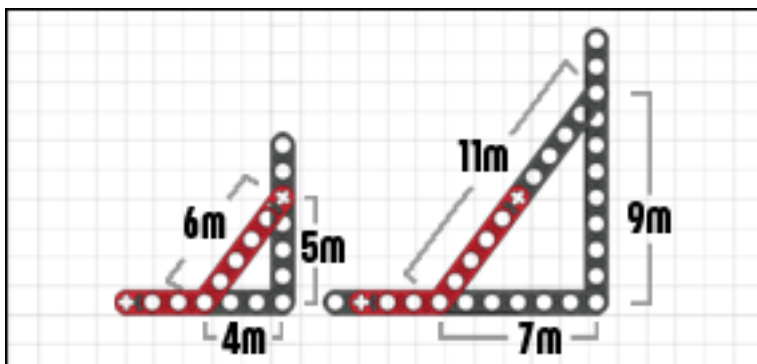
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second example is a stronger structure because the shape is closed, adding additional reinforcement to the frame.



When building a chassis and structures to support your functions in TECHNIC, it's easiest to build everything in 90 degree angles and to avoid odd angles. By building functional parts in rectilinear segments, cross-axes and connection holes between beams line up easier- this means that functions are easier to integrate into the structure, and strong structures are easier to build.

But what about styling? Unless you want your model to look like a box, you're going to have to build a few angles into your model. Let's have a look at some tricks to make building with angles easier.



Take a look at the diagram above and notice how the beams line up. These constructions are right triangles, meaning that one of the angles in the triangle is 90 degrees. The best way to build a right triangle with TECHNIC beams is to build with the proportions shown. If you change the lengths of any of the sides of the triangle, you may find that the triangle no longer has a right angle and is harder to build into your model.



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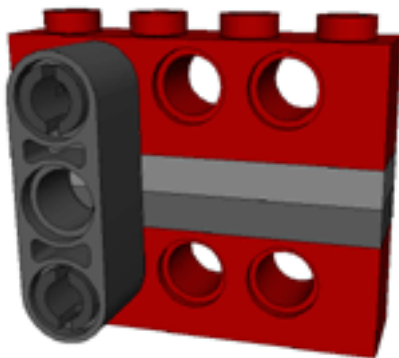
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Does the red angled beam in the diagram look familiar? Did you ever wonder why these beams have such a funny angle on them – not quite 45 degrees? It's not a problem with one of the robots at the LEGO manufacturing plant. It's to allow you to build these special right triangles.

Have a look at the diagonal beams in the diagram above and compare it with the grid. Notice that most of the holes don't line up. Beware of these holes! Building onto these holes is tricky because often they don't line up with other parts of your model.

So, why do the two triangular constructions above work? Because of the Pythagorean Theorem. Yes, a little bit of basic geometry. Don't worry; it won't hurt. The Pythagorean Theorem shows how the lengths of each side of a right triangle are related: the sum of the squared lengths of the sides is equal to the length of the hypotenuse (or long side, opposite the 90 degree angle) squared (or $a^2 + b^2 = c^2$). The triangle shown above is a special example because there are no fractions involved in the equation. Have a look. The length of the hypotenuse in the smaller triangle is 5M (it has 6 holes, but its length is 5M.) The lengths of the other sides of the triangle are 3 M and 4 M. So, the equation looks something like this: $3^2 + 4^2 = 5^2$. Simplified it is: $9 + 16 = 25$. Simplified even more: $25 = 25$. And we all know that 25 does equal 25. Got it? If you're a bit confused with the math, don't worry. You can still make super strong right triangles by following the example in the diagram above.

Want to know some more TECHNIC tricks? Good! We thought as much. Here's a good trick for building classic TECHNIC bricks into your models. Have a look at the construction below.



It shows that the distance between every other hole on a TECHNIC beam is equal to the height of two beams with two plates sandwiched between them. This allows you to combine studded TECHNIC beams and other LEGO System elements with TECHNIC and have everything line up. Handy, huh?

With these top TECHNIC tricks under your belt you're fast on your way to becoming a TECHNIC Master Builder.



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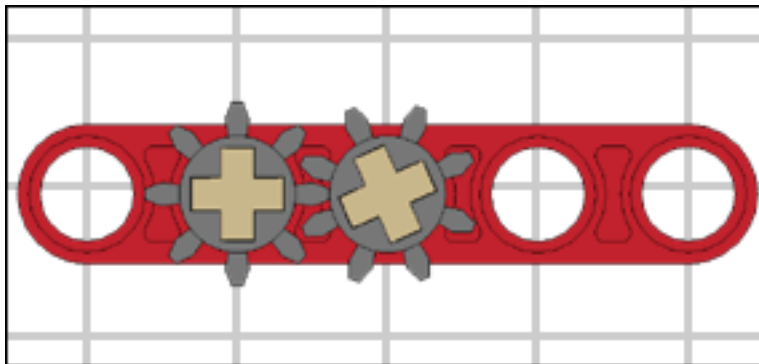
Gearing 101

In this lesson we'll learn some basic gearing concepts which can add motion and functionality to your TECHNIC creations.

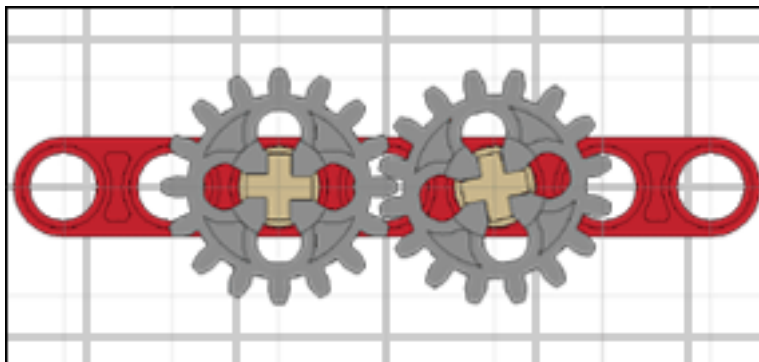
Here's where things get really interesting.

A gear is a toothed wheel. When two gears are next to each other, they spin one another. When a series of gears are aligned they make a gear train. By combining gears in different ways, a huge variety of effects can be generated. Gears are used in many things, from trains and planes to robots. In this lesson we will learn how to build working gear trains and control a gear's direction of spin.

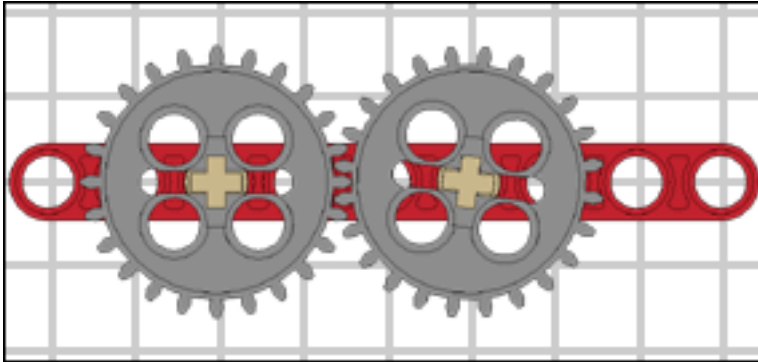
All TECHNIC gears are compatible with each other, but some combinations of gears are especially useful for builders. Try making some of these examples:



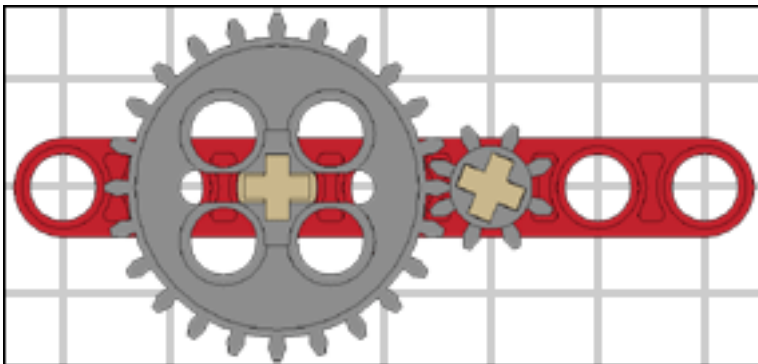
Two 8-tooth gears



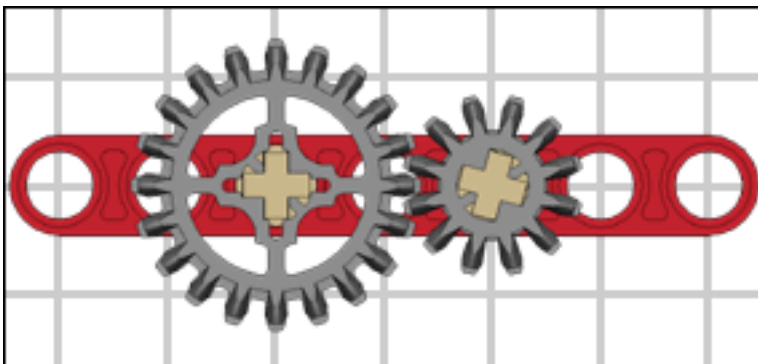
Two 16-tooth gears



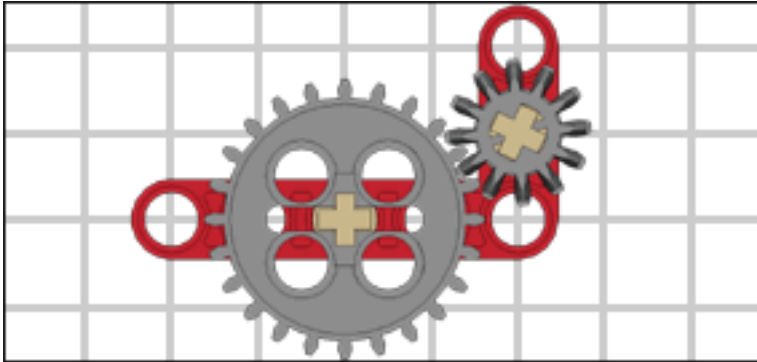
Two 24-tooth gears



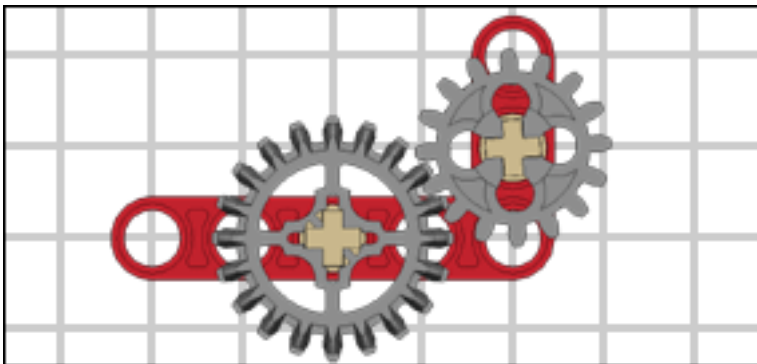
An 8-tooth gear and a 24-tooth gear



A 12-tooth gear and a 20-tooth gear



A 24-tooth gear and a 12-tooth gear

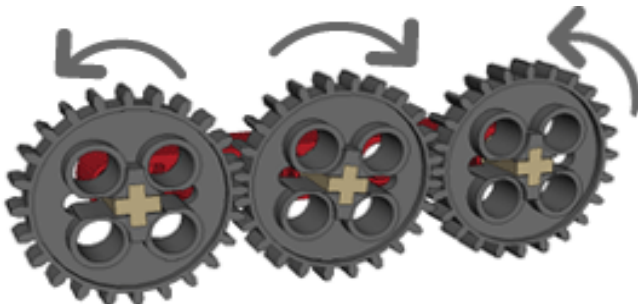


A 20-tooth gear and 16-tooth gear

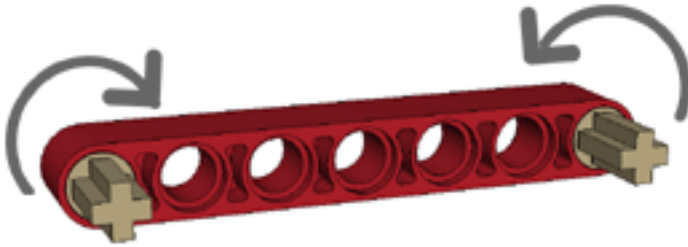
Keep these ideas in mind when working on your gearing – but remember that in a pinch, you can always just start snapping gears onto a beam to see what combination works the best!

So what kinds of things can you do with gears?

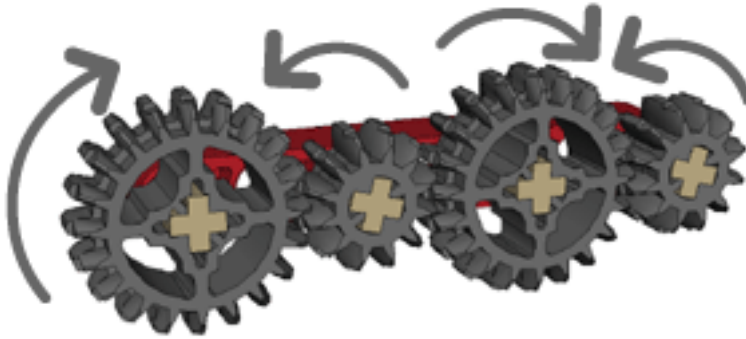
When two gears meet in a straight line, they spin in opposite directions. You can use this to change the direction of a rotating component in your model. Line up three gears and the first and last ones will spin in the same direction, while the middle one rotates the opposite way!



Here's a challenge for you! In the diagram below, if the connector peg on the left is spinning clockwise, can you build a gear train to make the peg on the right spin counter-clockwise?



Here's one possible solution!



And here's another!

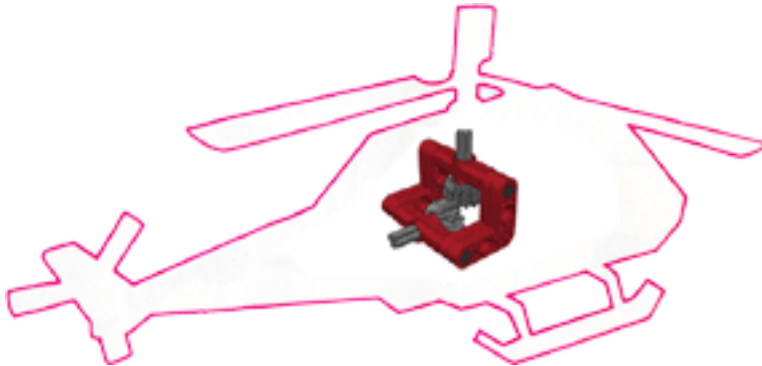




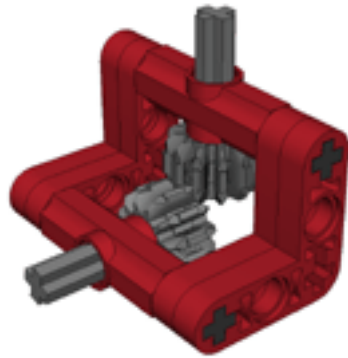
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Now that you understand how a gear train works in a line, let's see how you can use gears to change the axis of rotation. For example, you can link the rotation of a vertical cross-axle with the rotation of a horizontal cross-axle. Check out how it might be used in a helicopter!

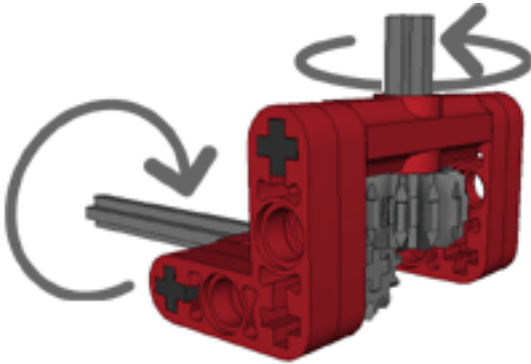


Let's build a simple mechanism that you can use in your own TECHNIC creations:

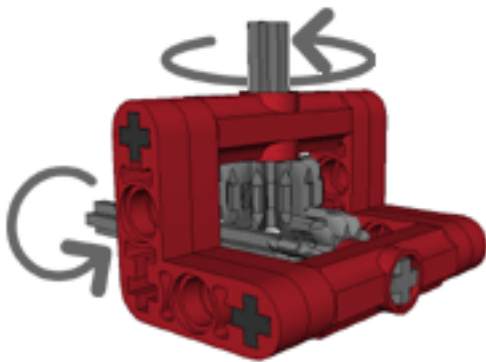


This type of gearing is often used for steering mechanisms in vehicles. The horizontal cross-axle is connected to the steering mechanism that moves the tires from side to side, and the vertical cross-axle is attached to the steering wheel on top of the vehicle. By turning the steering wheel, the driver can make the tires on the bottom of the vehicle rotate left or right.

Here's a handy trick to reverse the direction of the horizontal cross-axle's rotation. In the illustrations below, the horizontal axle of Construction A spins the opposite direction from that of Construction B. The constructions are the same, but the horizontal axle is positioned differently. This is an easy way to fix your model's steering if the controls are backwards.

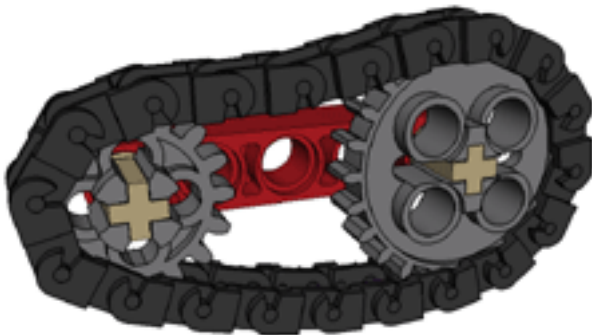


Construction A



Construction B

You can also use chains with your gears, just like on a bicycle!





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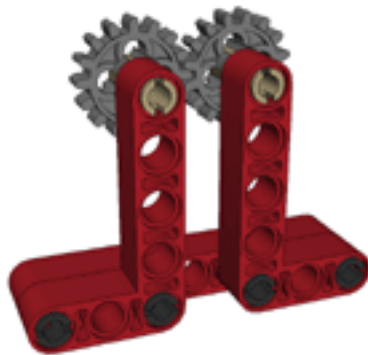
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Why do gears slip sometimes? Gears are designed to avoid slipping, but they can skip if they're not spaced correctly or are under too much stress. If you see (or hear) your gears slipping, try some of these troubleshooting tips:

- Make sure the gears are spaced so that the teeth mesh completely. If the teeth do not fully overlap, you might find that they slip when a large amount of force is applied to them. If the gears are positioned too closely together, they will create friction and won't rotate smoothly.

Ready for another challenge?

In the illustration below, the gears could easily slip. Can you figure out how to support them better and keep the teeth locked together?



There are lots of possible solutions to this problem. Here's one, using a 3M beam to keep the gears locked at a fixed distance apart.

