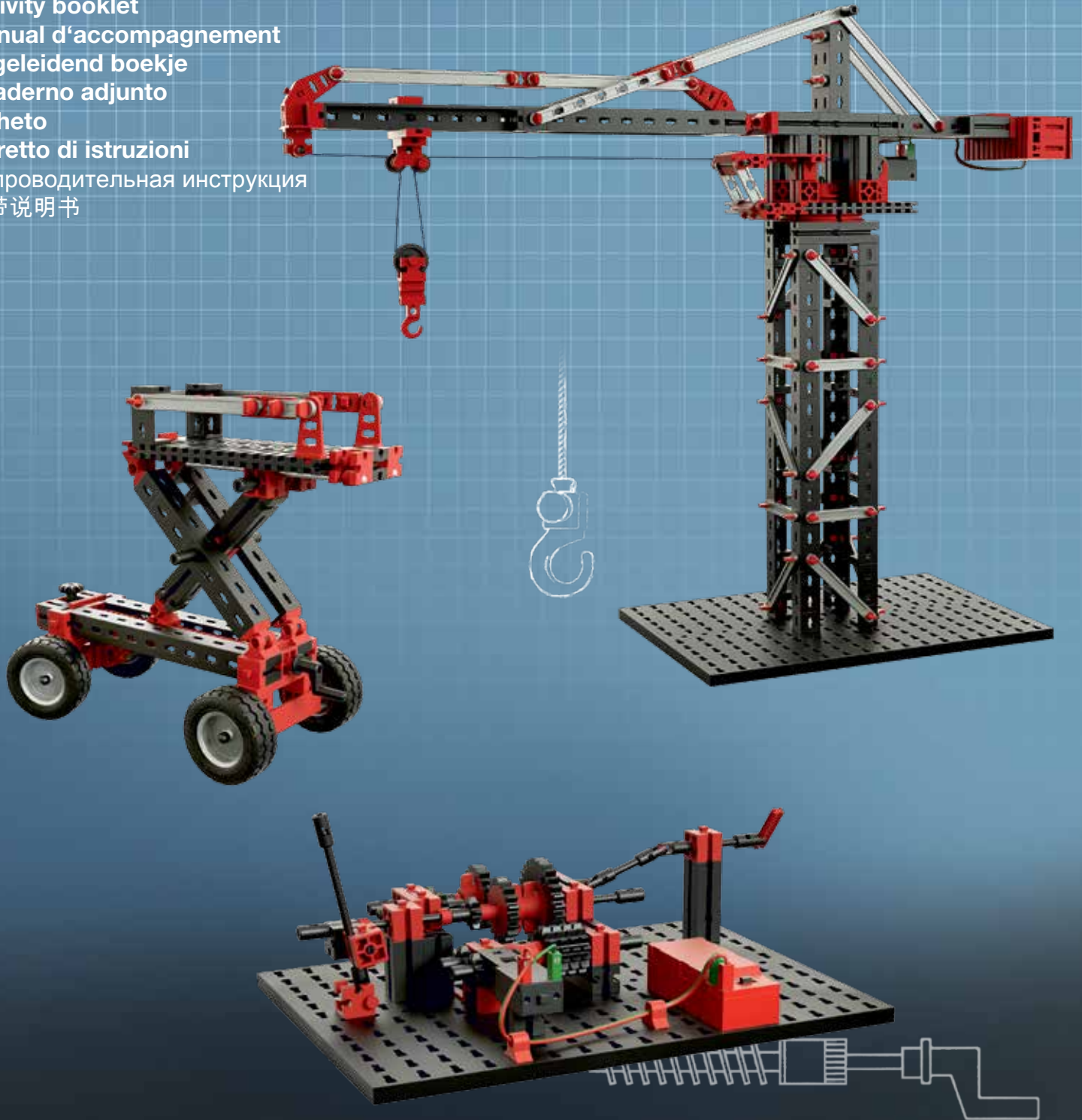




fischertechnik 

PROFI

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Mechanic & Static 2

30 MODELS

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Machines around us

► Who carries heavy loads around today? Who drills a hole in the wall with pure muscle power? Who still washes his clothes on a washboard? Almost nobody. The human being has invented many devices, which make his life and work easier. This began with the work mill for a mill and moved on to the jet engines for a Jumbo jet and then to the computer.

Devices that make your work easier or even do it for you are called machines in the technical language.

Machines can:	Examples:
● Move loads	● Truck, car, crane or excavator and so forth
● Machine materials	● Dough mixer, cement mixer or mixer and so forth
● Transforming electrical energy into kinetic energy	● Electric motor
● Process data	● Pocket calculator or computer and so forth

What is mechanics?

► Mechanics has to do with effects and forces, which affect rigid and moving bodies. Mechanics is divided into various areas such as statics, dynamics, kinetics or thermodynamics. We will limit ourselves to two areas: dynamics and statics.

Even in the ancient world, scientists studied the areas of mechanics. The old master builders of cathedrals built higher and higher churches that pushed the experimentation with the balance of forces to its limits. Today,

a structural engineer does the calculations for the stability of a building. His profession comes from the mechanics subarea of statics. You will learn more about this in the statics part.

Whenever machines or gear units are set in motion, they are dynamic. **Dynamics** describe the change of the movement variables, for example, for the rotation of a shaft, back-and-forth movements or the toothed gear transmission. So dynamics is the science of changes in movements. You will learn exactly what this is in the following chapters.

The Electric Motor

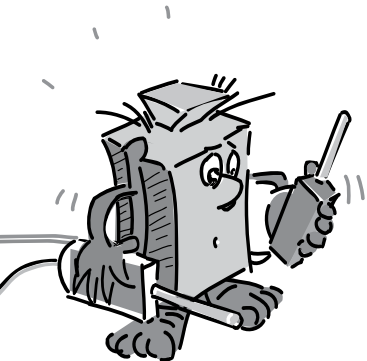


► A motor is a possible drive for a machine. There are two types of motors: the combustion motor and the electric motor. For example, a car is driven by a combustion motor. Of course, you don't have such a complicated motor in your construction kit, but you do have

an electric motor, which we will call the E-motor for short.

Electric motors are the drives for most of the everyday machines. They can be used everywhere where electrical energy is available.

► The electric motor in your construction kit has a very high number of revolutions per minute (RPM), which means that it rotates so fast that you cannot even see one single revolution. But your motor is very "weak," which means that it cannot lift loads and cannot drive any vehicle. To reduce the revolutions and the make the motor "stronger," you need a gear unit..



► A worm gear pair is best suited to reduce the high RPM of the motor. To do this, a worm gear is placed on the motor shaft, that is the rod, which extends out of the motor casing. The worm gear drives a toothed gear. This type of gear unit is used where high revolutions per minute are to be reduced in a small area. A worm gear pair works in a self-locking manner, which means that the worm gear can be driven by the worm gear pair, but on the other hand it locks the gear unit.

Worm Gear Pair

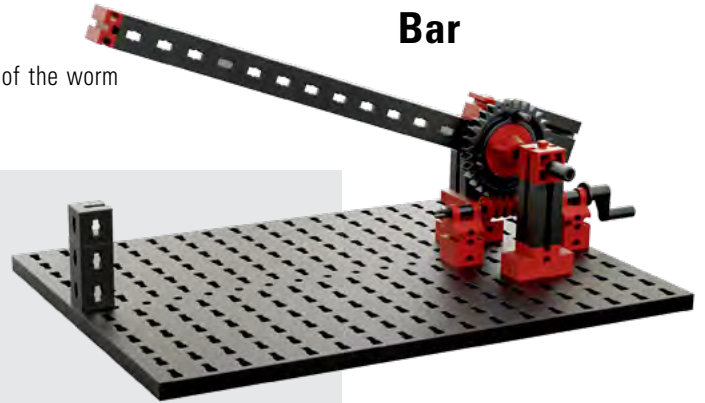
► Bars and cranes use this gear unit because here the safe locking of the worm gear keeps the bar or the attached load from "reversing" the drive..

Bar



Task:

- Build a copy of the bar model.
- Rotate the bar upwards with the crank. How many times do you have to turn the crank to put the bar in a vertical position?
- Try to pull the bar downwards with your fingers.
- What happens?



Of course, you had to turn the crank a few times to move the bar 90° . Were you able to pull the bar down? See, this is how a self-locking gear unit works. With the small crank, you could easily lift the big bar so you increased the driving force with the worm gear pair.

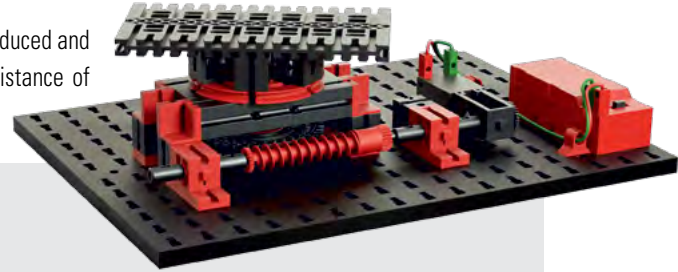
The worm gear pair has many advantages:

- It saves space.
- It reduces the revolutions per minute of the drive many times.
- It is irreversible.
- It increases the force of the drive.
- But, it also changes the direction of the rotational movement by 90° .

Turntable

► The mechanism of the worm gear is used in many machines. A simple example of this is the turntable, your next model.

For this model, the revolutions per minute will be reduced and the direction of rotation will be changed. The resistance of the loaded turntable must not stop the motor.



Task:

- Build a copy of the turntable.
- Put a pot with water or earth in it on the turntable plate,
- of course only a pot that fits on the plate.
- Can the little motor really rotate the big pot?



Toothed Gearing

► In this chapter, you will learn more about the gear units with toothed wheels. Toothed wheels are among the oldest and most robust elements of a machine. There are various types and sizes.

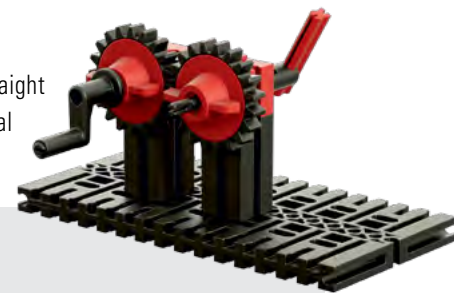
You know a function similar to toothed gearing from your bicycle. But here the toothed wheels are replaced by chain sprockets and a chain.

Using toothed gearing, you can transmit and change rotational movements. Toothed gearing can:

- transmit a rotational movement
- change the revolutions per minute
- increase or decrease the rotational force
- or change the direction of rotation

Crank gears

► In the following models, you will build toothed gearing with straight toothed cylindrical gears. Cylindrical gears are used if the rotational motion is to be transmitted to a parallel shaft.



Task:

- Build a copy of the crank gear 1.
- Turn the crank one time. How many times does the shaft with the second toothed wheel turn?
- Turn the crank clockwise. What direction does the driven gear turn and so
- the second shaft?



Mechanic & Static 2

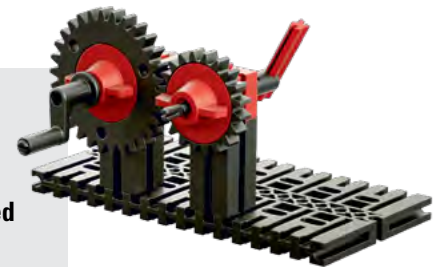
If you want to move a vehicle in this way, you would move very slowly. Also, you would go backwards. This model is only to show you how to build a simple gear unit and make calculations for the gear unit.

Calculation of the transmission ratio for the toothed gearing.

	Drive gear	Driven gear
Gear No.	1	2
No. of teeth on toothed wheel	Z_1	Z_2
Number of revolutions	n_1	n_2
Direction of rotation (left, right)		

Task:

- Build a copy of the crank gear 2.
- Turn the crank one time. How many times does the shaft with the second toothed wheel turn?
- Turn the crank clockwise. What direction does the driven gear turn and so the second shaft?



If you would move a vehicle in this way, you would move somewhat faster than with your first model. Calculate the transmission ratio for this gear unit as well.

Calculation of the transmission ratio for the toothed gearing.

	Drive gear	Driven gear
Gear No.	1	2
No. of teeth on toothed wheel	Z_1	Z_2
Number of revolutions	n_1	n_2
Direction of rotation (left, right)		

Inclined Plane

► Have you ever stood on top of a hill with your bicycle and weren't sure which of the two roads you should take to go downhill? Should you take the steep road that picks up a fair amount of speed, or the level path that's slower, but takes you farther? But is this really the case? Do you really get farther riding on the level path than on the steep slope? Let's find out by doing an experiment.

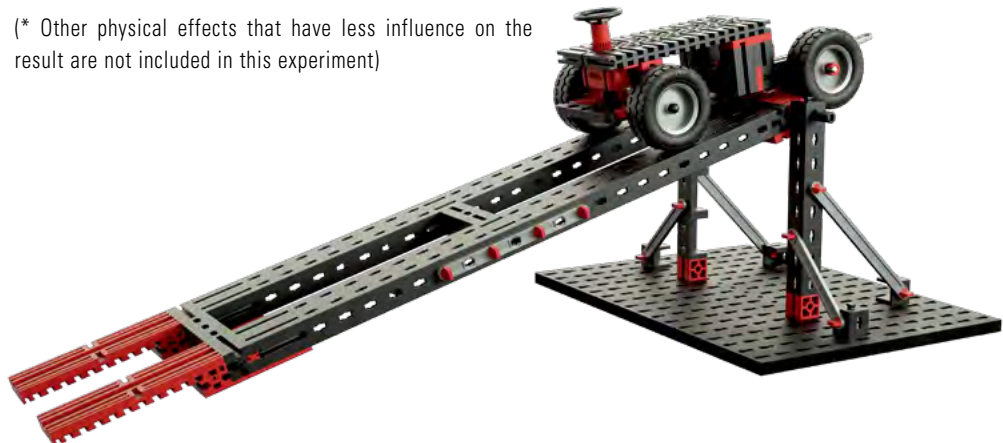
Task:

- **Build the "inclined plane" model with the related vehicle, as described in the assembly instructions.**
- **Place the vehicle exactly at the top in the starting position so that it rolls downwards parallel to the ramp. Use a tape measure to measure the distance traveled and enter the measurement in the table. Repeat the process two more times, since measuring three times is more accurate than once.**
- **Now shorten the ramp to about half the length by removing some building blocks. Next, repeat the three test runs and enter the new measurements in the table.**

	Long ramp	Short ramp
1. Distance in cm:		
2. Distance in cm:		
3. Distance in cm:		

Are you surprised? Whether the ramp is steep or flat makes (almost) no difference. So, what influences the distance traveled? In our experiment it is the stored potential energy*. This is energy that an object has due to its elevation. It is like the car on top of the ramp, or you with your bicycle on the hill. You converted kinetic energy into potential energy when you rode up the hill. You can turn this particular amount of potential energy back into kinetic energy when you ride back down the hill. It doesn't matter whether you convert it when traveling at a uniform or irregular speed: you still cover the same distance.

(* Other physical effects that have less influence on the result are not included in this experiment)



► Now you have already learned a lot about gear units and you can try out this knowledge on a model. Build vehicle 1. With the motor and the gear unit you now have a real vehicle drive.



Vehicle Drives



So that you can go even faster, build a copy of vehicle 2. Now your mobile travels 1.5 times as fast as the one before. But this transmission ratio has its problems on a mountain.

Vehicle 3 has a "reversed" gear unit construction compared to vehicle 2. How does its speed change in comparison to the other models?



With the three toothed gears, you have created a transmission ratio of 1:1 with the same revolutions per minute and the same torque. Your second model has a transmission ratio of 1:1.5 and a reduced torque. This means that it is faster but has less "force." Vehicle 3 has a transmission ratio of 2:1 and goes slower than the other two and that's why this is called a reduction ratio. This type of transmission has the advantage that it is "stronger," meaning it has a higher torque. This effect is used, for example, with a tractor. It travels slower than a car of course, but it has much more power. You know all three gear unit transmission ratios from your bicycle gear shift. In the front you drive the large wheel and in the rear the small gear pinion to travel faster on the level. But on a mountain you certainly shift to a smaller transmission ratio such as 1:1 or when it is really steep to 2:1.

► You know all three gear unit transmission ratios from your bicycle gear shift. In the front you drive the large wheel and in the rear the small gear pinion to travel faster on the level. But on a mountain you certainly shift to a smaller transmission ratio such as 1:1 or when it is really steep to 2:1.

Toothed Gearing with Chains



with each other by keeping the machine parts in a certain interaction.

If there is a greater distance between two shafts, then a tension gear unit is used to span this distance. Belts or chains are used as a tension medium. They connect the drive gear and the driven gear over longer distances





Task:

Build a copy of the vehicle with chain drive, first only with a crank instead of a motor.

- **Turn the crank one time. How many times does the gear turn?**
- **Turn the crank clockwise. In what direction does the gear rotate?**

Calculation of the transmission ratio for toothed gearing

	Drive gear	Driven gear
Gear No.	1	2
No. of teeth on toothed wheel	Z_1	Z_2
Number of revolutions	n_1	n_2
Direction of rotation (left, right)		

You have such a gear unit on your bicycle. The distance between the pedal drive and the rear wheel is covered by a chain. On a mountain bike or a racing bike, of course you have not only one gear, but you can choose from many gears. This means that you adjust your speed depending on the force needed and the force to be transmitted and the revolutions per minute. In this case, your toothed wheels are not called cylindrical gears, but chain sprockets.

Install the motor in your vehicle with a chain drive. This is exactly how the transmission is done with a moped or motorcycle. Of course, you can now build your own motorcycle from your fischertechnik parts.

Mechanic & Static 2

► A wide variety of systems are available to make vehicles steerable.

We will take a look at two of them: axle pivot steering of your motor-driven vehicle and fifth wheel steering of the handcart.

In more modern axle pivot steering systems, it is not the wheels that are turned together with a single shaft axle, as is still the case with fifth wheel steering; instead, pivoting wheels are connected with a steering system.

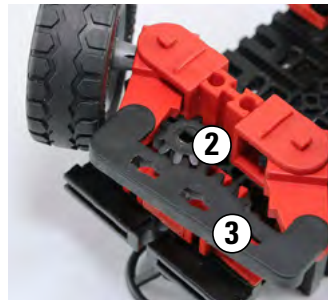
Steering starts with the steering wheel. Inside the steering wheel is a rod with a small toothed gear (pinion) mounted on each end. The pinion meshes with a transverse rack, which also has teeth. Now if you turn the steering wheel to the left or right, the pinion also turns and moves the rack to the left or right. Pivoting hub carriers with levers are mounted on the ends of the rack. The lever on the hub carrier is connected with the rack. When the rack moves, it twists the lever and with it the hub carrier with the attached wheel..



Comparison of the Steering Systems



1 Steering column



2 Gear
3 Transverse rack



4 Drawbar



5 Pivot pin
6 Fifth wheel
7 Axle



pivot pin in the floor panel of the wheel is what you steer.

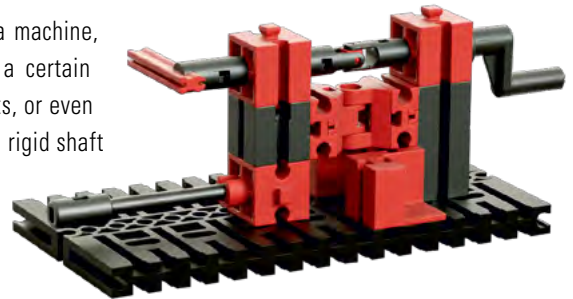
► Fifth wheel steering is the simplest and oldest steering system designed by humans. It is sturdy, easy to set up and can even be made of wood. The Celts (approx. 600–30 BC) developed it long ago for their carts and wagons. It is precisely because they are so simple and robust that they are still used today for many trailers, pull carts and horse-drawn vehicles.

Fifth wheel steering has an articulated type of support frame for the axle and wheels. This frame is mounted on a vehicle. A drawbar mounted to the fifth



Cardan Joint

► In drive technology, there is usually a motor and a machine, which is to be powered. Often, both elements are a certain distance away from each other, are at different heights, or even move back and forth. If you would connect both with a rigid shaft then it would inevitably break. On the other hand, a soft flexible shaft would be too weak to transmit large forces.



Task:

- Build the cardan joint as described in the assembly instructions.
- Move the driven part into various positions while turning the crank and observe the movement that the joint must make—particularly when in a position that involves significant bending.

Isn't it amazing how you can just turn a corner with a rotating movement?

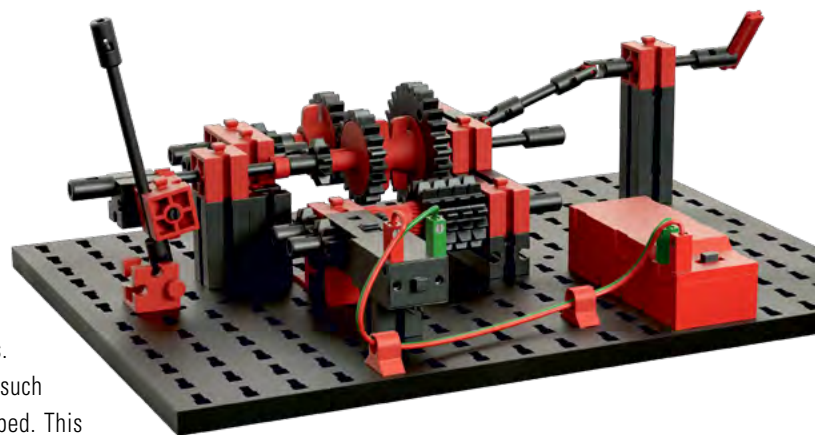
The cardan joint, also known as a universal joint, is a joint that is flexible, yet also strong.

Without this joint, nothing would turn in many areas of our everyday life. A good example of this is the cardan shaft described in the following "gearbox" model.

Gearbox with Several Gears

► With the following construction, you expand the simple toothed wheel transmission with gear changing with several gears. This is how a gear unit is developed such as in an automobile, a drill or a moped. This model has a compound gear unit, which means a gear unit, which consists of more than two toothed wheels.

Experiment with the transmission effect of toothed wheels and pairs of toothed wheels placed in a series one after the other.



The twice "bent" shaft at the gearbox output is particularly interesting. With this cardan shaft, you can spatially offset rotational movement while still going around the corner. This is important, for example when the component to be driven constantly bobs up and down, such as in the case of the rear axle of a car.

Task:

- Build a copy of the gear unit.
- Turn the motor on and move the "gear shift lever" slowly from gear 1 to gear 3. Insure that the toothed wheels for a gear mesh with each other exactly.
- Write down your observations



Observation of the individual gears

Gear No.	1	2	3
Observation faster, slower			
Direction of rotation same, opposite			

This gear unit in gear 3 goes in a different direction than in gear 1 and gear 2. This is because that here, three toothed wheels are in a series.

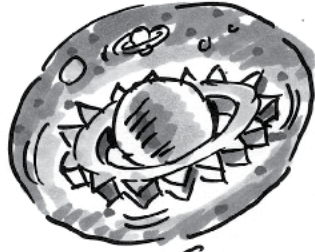
When an uneven number of toothed wheels are in a series, then the driven gear has the same direction of rotation as the drive gear. This effect is used for a car to drive backwards.

Other experiments:

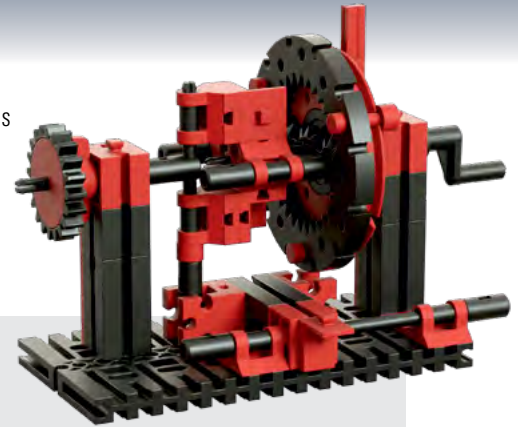
- Build your own model with different numbers of toothed wheels in a series.
- Replace the turntable with a winding drum. Now you have a cable winch like in a crane for various heavy loads.
- Can you put more gears into your gear unit? Experiment with the toothed wheels in your fischertechnik construction kit.
- Expert task: Build a gear unit with a chain.



Planetary Gear



► A planetary gear is a very complex system with various toothed wheel types. It is used in many areas, for example, as a stirrer in a kitchen appliance or as an automatic transmission in a car. But, there the construction is somewhat more complicated.



Task:

- Build a copy of the planetary gear.
- Turn the crank, this is the "drive", and observe, which shafts, toothed wheels and toothed wheel combinations you rotate with the crank.

Using the slider, that is the name of the lower part of the lever for your model, you can stop the planet carrier or the hollow wheel so that one of the two parts cannot rotate.

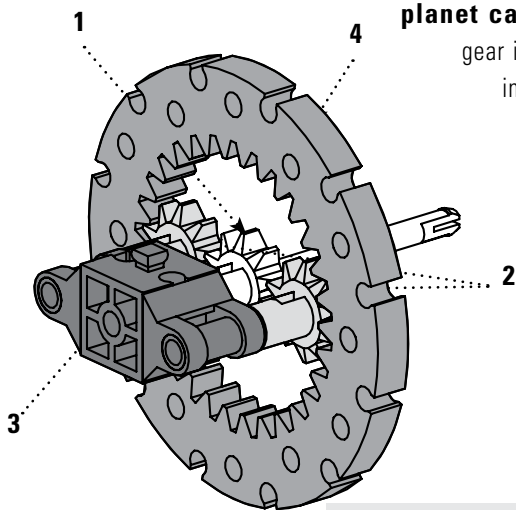


The purpose of a planetary gear is simple. It allows the change of the transmission ratio under load, which means without separation of the flow of force between the drive and the driven gear. Due to the internal tothing of the hollow wheel, the toothed wheels are arranged in a particularly compact manner. For the reverse gear for a planetary gear, no additional shaft with a reverse idler gear is necessary.

In the simplest case, the planetary gear consist of the **sun gear (1)**, **planet wheels (2)**, the **planet carrier (3)** and the **hollow wheel (4)**. For this simple planet wheel set, a sun gear in the middle is connected form-closed by means of several planet wheels with an internally toothed hollow wheel. The sun gear, planet carrier or the hollow wheel can drive, be driven or stalled. To try out your gear unit properly, you have the slider.

Without an additional toothed wheel, by stalling the planet carrier (3) you can adjust the gear unit so that the output is done one time through the planet carrier and one time through the hollow wheel.

This process is used in vehicle technology to shift into reverse gear. To do this, the drive (the crank) must be connected with the sun gear and the axle drive with the hollow wheel.



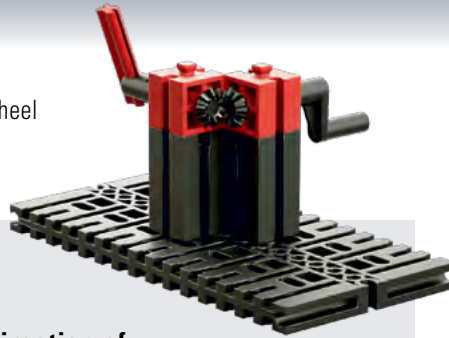
Task:

- Test the characteristics of your planetary gear by first holding the planet carrier in place and then drive the gear unit on the hollow wheel.
- Fill in the following table:

Drive	Hollow wheel	Planet carrier
Direction of rotation		
Reduction ratio		



► With the bevel gear, you can learn how a simple toothed wheel transmission works.

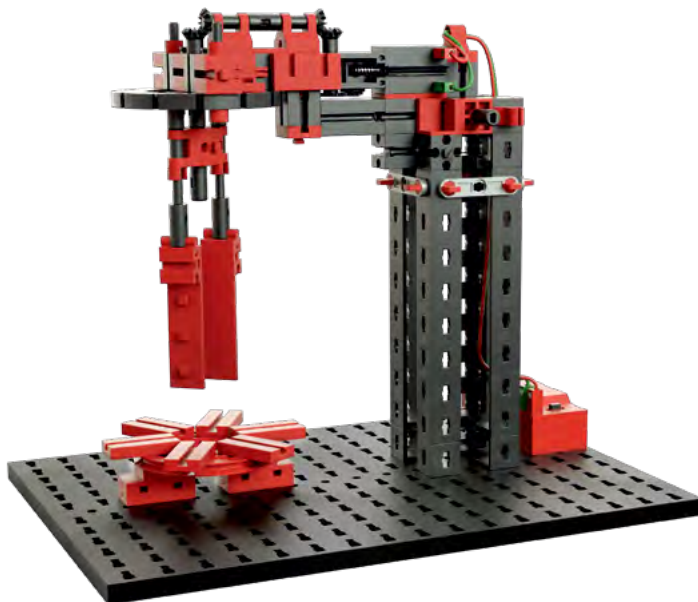


Bevel Gear Unit

Task:

- Build a copy of the gear unit model.
- Observe how the revolutions per minute, direction of rotation and the torque change with this model.

This gear unit only changes the direction of rotation by 90°, but the revolutions per minute and torque remain the same.

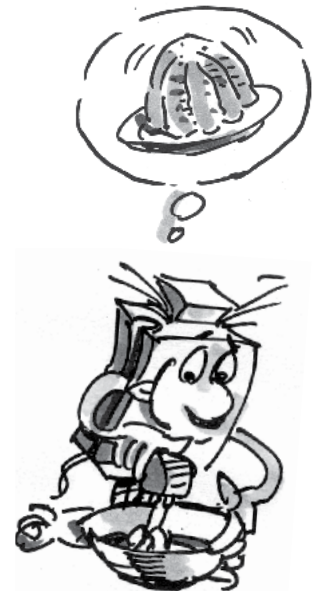


► This model combines the bevel gear unit and the planetary gear. Build this model according to the construction instructions.

The fischertechnik stirring device is a model for real pros. Do you know all toothed wheels and types of gear units that are interacting here?

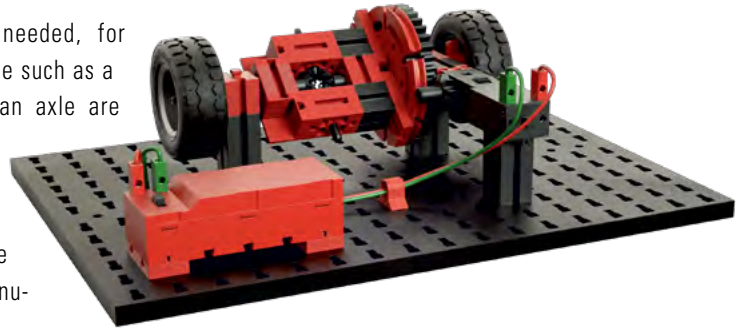
You can make very interesting variations with this model. Modify it according to your imagination. You can put a cup on the base and stir the contents.

Kitchen appliance



Differential gear

► A differential is always needed, for example, for a multitrack vehicle such as a car when several wheels on an axle are driven. Differentials have two purposes: the distribution of the drive power to two axles and the compensation for the difference in revolutions per minute between these branches.



With this function, the differential is used at two locations:

An **axle differential** is used on the axle to distribute the power from the cardan shaft to the two drive shafts to the wheels.

A **central differential** is used between two axles to distribute the power between the front and rear axle.

Task:

- **Build a copy of the gear unit model.**
- **Observe how the revolutions per minute, direction of rotation and the torque change with this model. Hold one driven gear and then release it and hold the other one, then hold the rotating body (the holding fixture for the center bevel gears) in the middle.**
- **Record your observations in the table.**



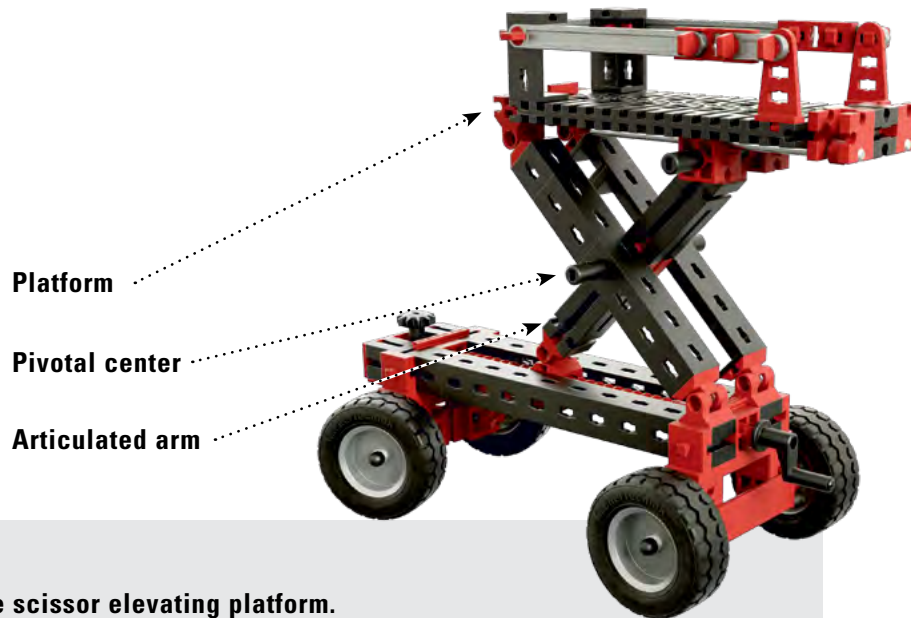
Hold	Driven gear 1	Driven gear 2
Revolutions per minute		
Direction of rotation		

The differential appears to be a real magic gear unit.

It is used the most in cars: when a car travels around a curve, the outside wheel travels a greater distance than the inner wheel. Without a differential, the driven wheels would be rubbed off on the road and would wear faster. The differential on the axle has one other characteristic: it distributes the torques in the same ratio (50:50) and transmits these to the wheels.

► The scissor elevating platform shows you how to transform a rotational movement into a parallel up and down movement with the help of a screw spindle, joints and levers.

Scissor elevating platform



Task:

- Build the scissor elevating platform.
- Put a cup with water in it on the platform.
- How do the platform and the cup move when you turn the crank?

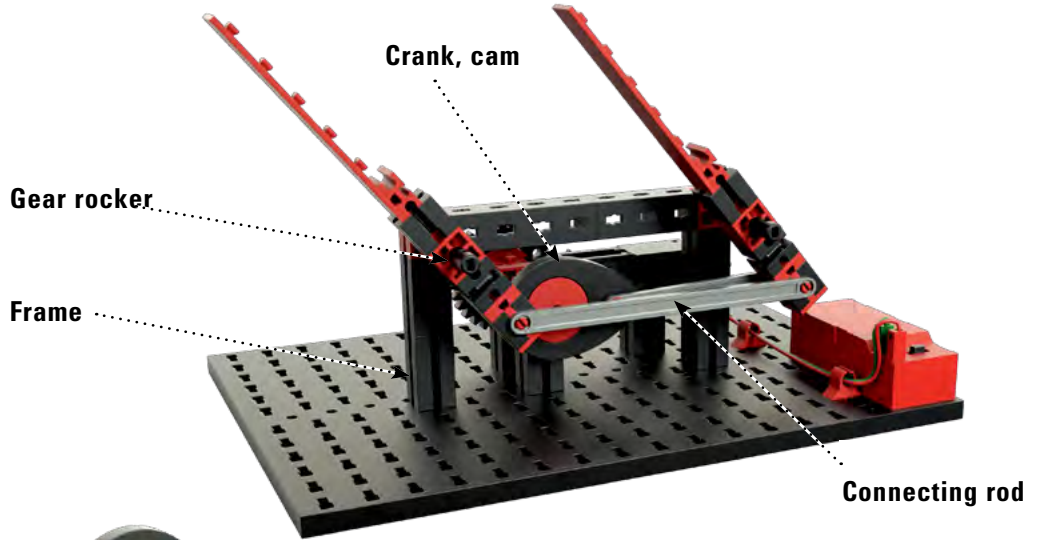


The screw spindle moves the worm nut back and forth. Through the joint, this movement moves the platform up and down. Since the pivotal center for both joints is in the common center, the lifting, that is the up and down movement of the platform, runs parallel to the screw spindle. Both joints move the same distance like scissors. That's why it is called a scissor elevating platform.

Coupler Mechanism

► Do you really know how a windshield wiper works? The next model shows you how it works. Here, a rotational movement is transformed into a back-and-forth or oscillating movement. To do this, you need a crank or a cam disk. This gear unit is called a crank-rocker gear unit. It transforms a rotational movement into a straight line movement and as a double four-bar chain consists of the following parts:

Windshield wiper



Four-bar chain



► The four-bar chain consists, as the name implies, of four joints, that is points, at which something can rotate. A simplified diagram of the four-bar chain shows you how it works. Do you recognize the components?

Task:

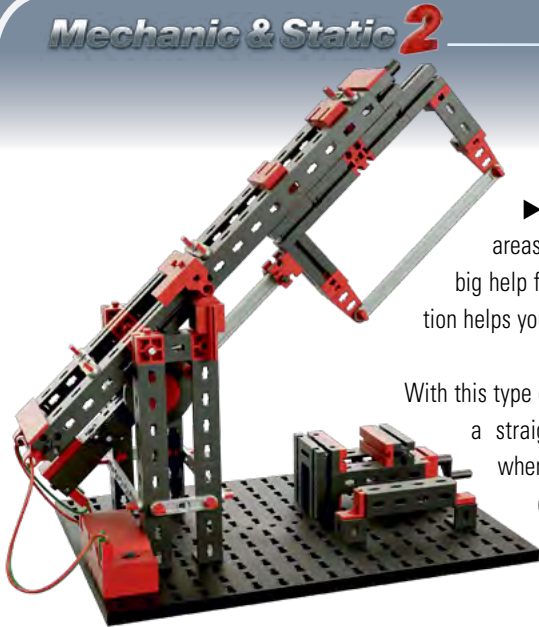
- Build the four-bar chain.
- Observe how the individual components interact.
- Which components move and which ones do not move? Describe the type of movement in the table.

Component	Moves: yes, no	Type of movement
Crank		
Connecting rod		
Gear rocker		
Frame		



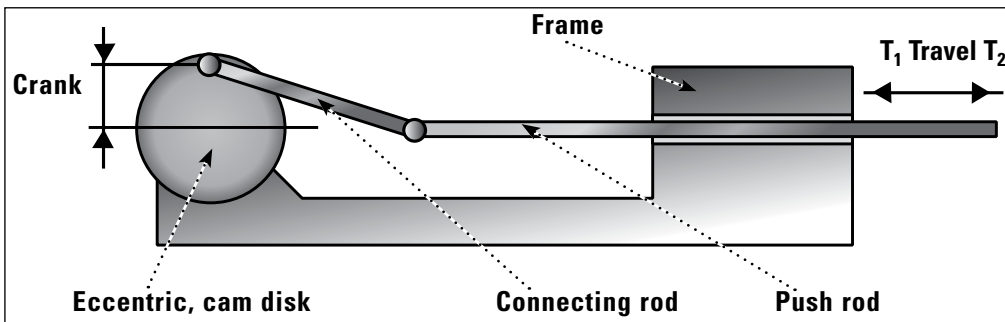
The frame is rigid and absorbs the movements. The crank must be able to make entire revolutions and the connecting rod transfers the movement of the crank to the gear rocker. The gear rocker only moves in an arc because it is fastened to the frame. In order that the gear unit can work, the lengths of the four components of the crank gear rocker must be in a certain relation to one another.

Mechanic & Static 2



► The effect of the crank gear rocker is used in other areas. For a long time, the power hacksaw machine was a big help for the metal construction builders. Its simple construction helps you to better understand a coupler mechanism.

With this type of gear unit, a rotational movement is transformed into a straight-line back-and-forth movement. The end points, where the saw cannot go any farther, are called the dead center points T1 and T2.



You can use the pawl (to the right of the power hacksaw machine axle) to secure the saw frame in the upper position.

Task:

- Build a copy of the gear unit model.
- Measure the stroke of your saw.



► Four thousand years ago, to determine the price of an item, the quantity of the item was compared to weights. This was done using a beam and scales, with which the balance of forces of two weights was measured. For your model, this is a beam attached at the mean pivotal center and the beam has a bowl at each end. Both indicators in the middle of the weighing beam must be in line when the forces are balanced.

Task:

- Build a copy of the beam and scales.
- Put a fischertechnik building block in both weighing bowls. Are your scales working properly?
- Now look for two objects, which have the same weight in your opinion. Put them in the weighing bowls.
- Were you right?



These scales work according to the principle of levers of equal length. A lever is a straight beam, which is attached in a manner allowing it to rotate and on which two forces act. The distances between the application points of the forces and the pivotal center are called the lever arms. Both sides beside the pivotal center are of equal length and equal weight. You know the principle of these scales from a teeter-totter. To have the levers in balance, the weights on the levers and their distance from the pivotal center of the scales must be the same.

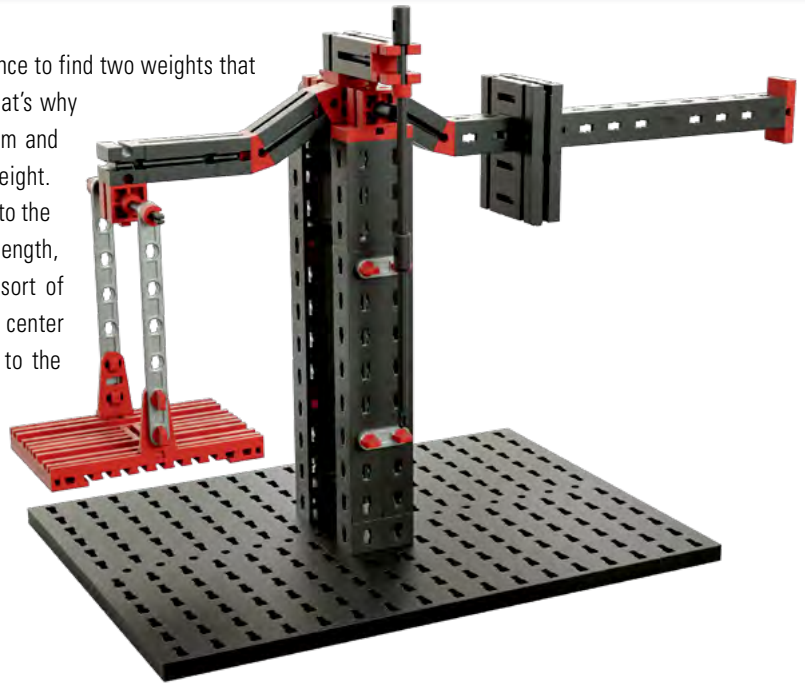
Lever

Beam and scales



Scales with Sliding Weight

► You have to have a bit of patience to find two weights that have exactly the same weight. That's why a further development of the beam and scales is scales with a sliding weight. These scales also work according to the principle of levers of the same length, but here torques are used as a sort of trick. Both sides beside the pivotal center are the power arms. The further to the outside that a weight hangs on a power arm, the higher its force. With the help of the slider, the torque on a power arm can be changed. The arm with the weighing bowl is called the lift arm.



Task:

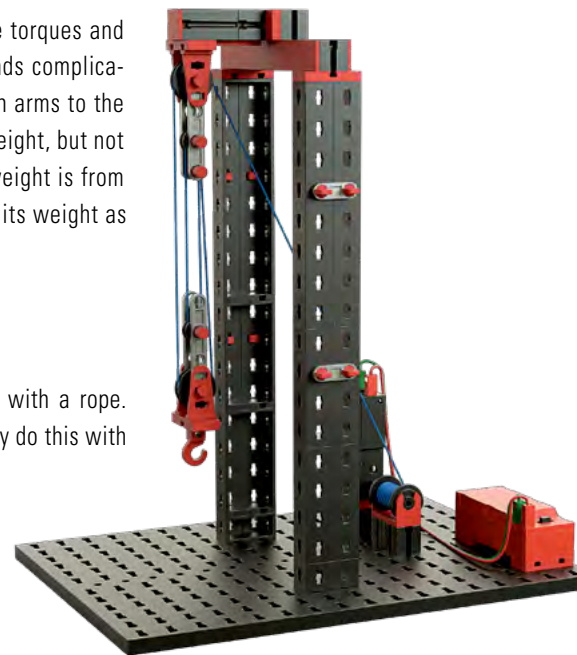
- Build the scales with a lift arm and power arm and sliding weight.
- Move the sliding weight so that the scales are balanced when no weight is in the bowl. The indicator in the middle of the scales helps you to do this.
- Put a weight in the weighing bowl. Balance the scales with the sliding weight.



Rope Pulleys, Lifting Tackle

To put a lever in balance, the sum of the counter-clockwise torques and the sum of the clockwise torques must be equal. This sounds complicated, but it is really not that difficult. The law says that both arms to the left and right of the pivotal center have to have the same weight, but not that they have to be the same length. The farther away a weight is from the pivotal center, the greater the force of the lever and so its weight as well.

► Just imagine that you would like to pull your friend up with a rope. Although, he weighs exactly the same as you do, you can only do this with an enormous expenditure of force. The rope pulley on the ceiling only helps you to hold, but not to lift. The lifting tackle model does give you some possibilities for lifting heavy loads very easily.



Mechanic & Static 2

Lifting tackle with 2 rope pulleys

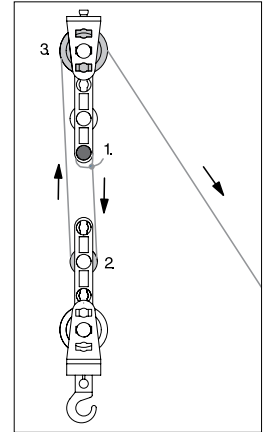
Task:

- Build the lifting tackle model with two rope pulleys, one fixed and one loose rope pulley.
- Hang a weight on the hook.
- Pull on the rope and measure how far you must pull to raise your load 10 cm.
- Do you need a lot of force to do this?
- Record your observations in the table.



	Length pulled in cm	Effort by feel	Number of rope pieces
2 rope pulleys			

With this model, the force used was reduced by half. What about the length pulled?



Lifting tackle with 3 rope pulleys

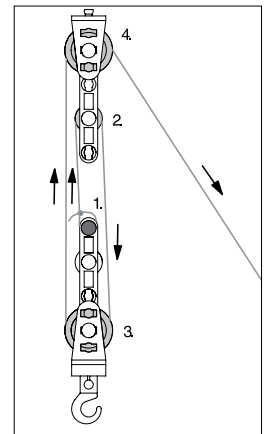
Task:

- Expand your first model to a lifting tackle with three rope pulleys.
- To do this, look at the construction instructions.
- Pull on the rope again and measure how far you must pull now to raise your load 10 cm. Do you need a lot of force to do this?
- Record and compare your observations in the table.



	Length pulled in cm	Effort by feel	Number of rope pieces
3 rope pulleys			

Now that you know how a lifting tackle works, you can build a lifting tackle with four rope pulleys. In addition, a motor will be installed to replace your force.



Lifting tackle with 4 rope pulleys

Task:

- Expand the model to a lifting tackle with four rope pulleys and a motor.
- Using regular rubber bands, attach a wallet with coins to the hook.
- Can the motor lift the coins?



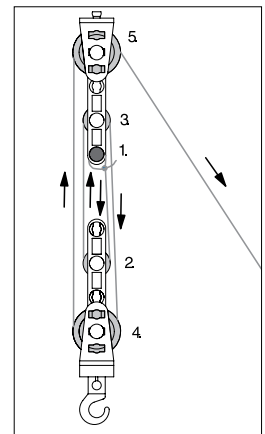
To be able to lift heavy loads with little force, you need lifting tackles with two, four or six pulleys. If the weight of the pulleys and the frictional forces are neglected, the lifting tackle reduces the force, depending on the number of pulleys, to one-half, one-fourth and one-sixth.

For this lifting tackle, the motor must only lift one-fourth of the load.

However, this does have a disadvantage: when the load is lifted 10 cm, how far must your motor roll the rope up.

- 10 cm 20 cm 30 cm 40 cm

Physics understands the way your lifting tackle works and has invented a law for this and this law is called the "Golden Rule". It states: "Work cannot be saved, whatever is saved on force, must be added in time and distance!"



The World of Statics

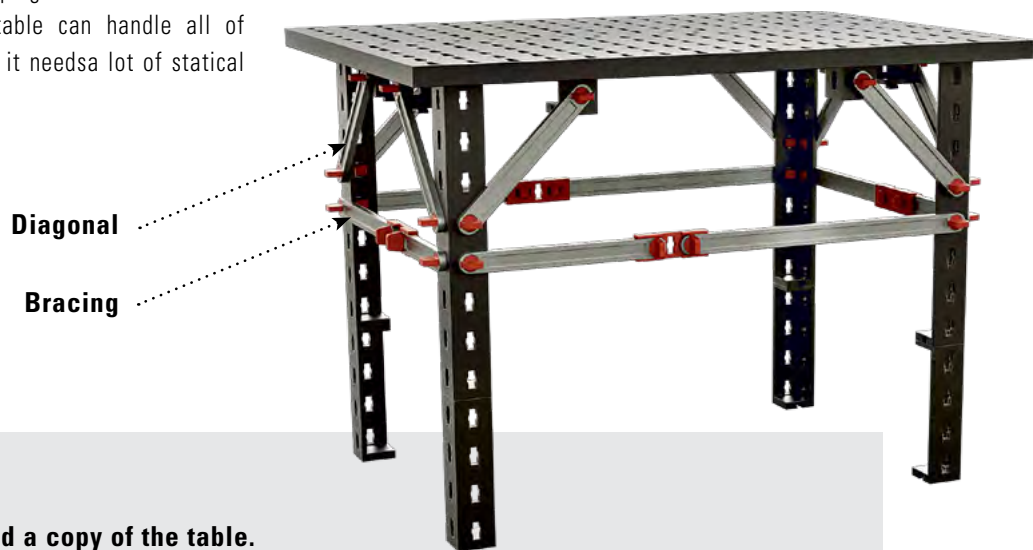
► Statics studies conditions, under which the forces acting on a body are in balance. This makes statics the basis for all calculations and designs of constructions such as bridges or houses.

Various forces act on components of statics. The weight of a construction is called dead weight. The weight of people, furniture, plates or even cars is called traffic load.

Table

► Your table is also a statical object. It carries its own weight, that is the dead weight, and the traffic loads as well. These are plates, cups, food or drinks, which are on the table, but this also includes accidentally bumping into the table.

So that a table can handle all of these loads, it needs a lot of statical specialties.



Task:

- Build a copy of the table.
- Insure that the diagonals are correctly connected.
- First, put a load on the table from above. Next, press on the table top from the side and then against one of the table legs. What happens in each case?



The statical characteristics of your model table are the angled table legs. They are stable on two sides due to the angle. The frame construction of the table also includes diagonals and braces. The yellow diagonals between the table legs stabilize the frame with respect to pressure and stress. But, the crowning moment of statics are the connection points, which form triangles. Triangles are also stable when the rods at the connection points have movable joints.

Such triangles are called statical triangles. So your model table is statically stable in three aspects. In statics, all connection points are called nodes

Task:

- Remove the braces and place a load on the table. What effect does this have on the statics of the table?
- Put the braces back in. Remove the diagonals. Place a load on the table again. How stable is your table now?
- Now remove the braces. Place a load on the table. What do you observe?

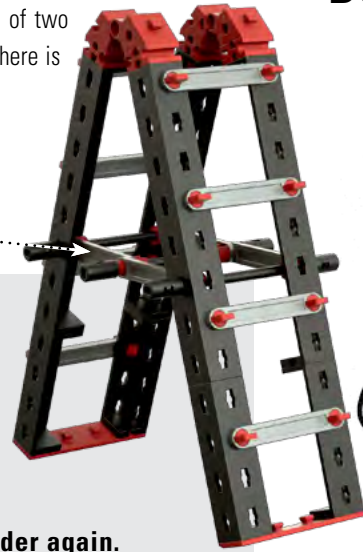


Mechanic & Static 2

► The double ladder has a very simple statical construction. It also has angled legs with strut bracing. The strut braces serve as rungs for the ladder. The double ladder consists of two individual ladders, which are connected at a pivotal center at the top. In addition, there is bracing of both ladders in the lower part

Double Ladder

Bracing



Task:

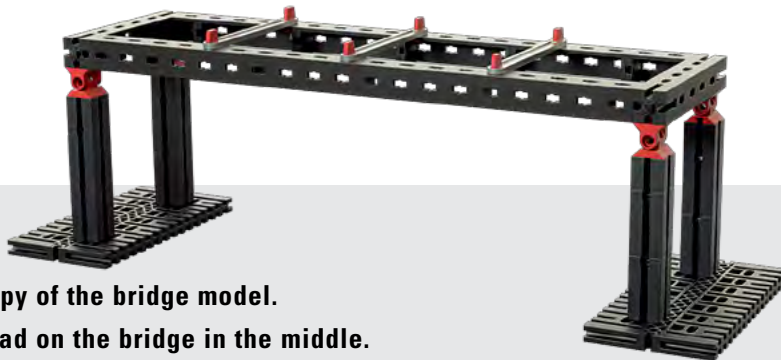
- Build the double ladder, but first without any bracing.
- Set the double ladder up and place a load on it by pressing on the rungs and the upper pivotal center. Does the ladder remain stable?
- Now, install the bracing on your ladder. Now test the ladder again. Does the ladder remain standing now



A double ladder consists of two halves that are the same, which are connected at a pivotal center at the top. Depending on the angle set for both halves, the ladder can remain standing without any bracing. But at a certain point, the "feet" of the ladder slip and the ladder halves are pushed away from each other. The bracing stabilizes the ladder.

► An optimal bridge has four characteristics: it is safe, long, cheap and looks good. With your first bridge model, you will get to know a classic of bridge building.

Girder Bridge



Task:

- Build a copy of the bridge model.
- Place a load on the bridge in the middle.
- Where could this bridge be used?



This one-field girder bridge is excellently suited for low loads and small span lengths. It fulfills all requirements. However, if the distance between the supports is greater, the bridge loses its stability.

Bridge with Underbeam

► The bridge with underbeam reminds one of suspension bridges, which span wild gorges. But this bridge has almost nothing in common with the design of a suspension bridge. You will find out why this is so during experiments with the model.



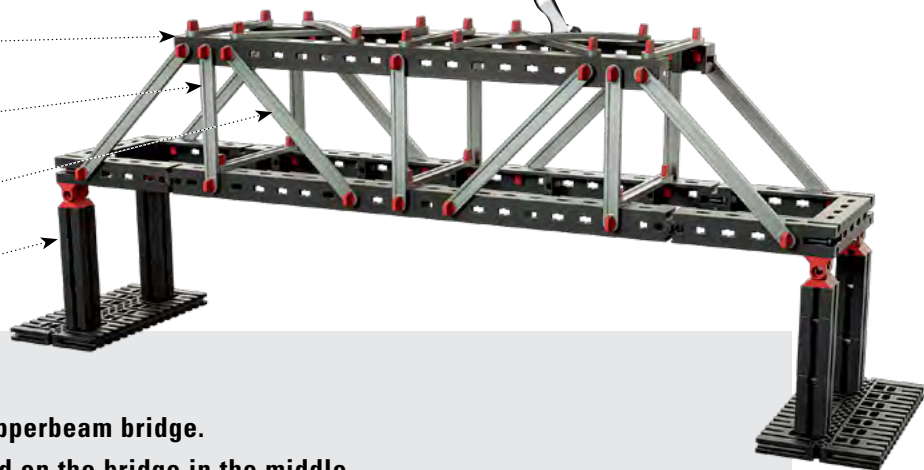
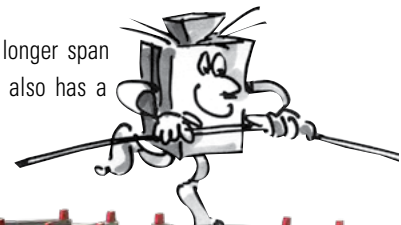
Task:

- **Expand your first bridge model to a bridge with underbeam.**
- **Place a load on the bridge in the middle. Now use a weight that is somewhat heavier**

From the load experiments, you certainly found that your bridge is very stable and can withstand large compressive forces. The bridge with underbeam functions due to its trussed construction. This type of construction is suited for large loads, but not for big span lengths. The greatest span lengths are reached with suspension bridges, but they cannot withstand such great forces. The bridge with underbeam and the suspension bridge only look similar. From a statics viewpoint, they are completely different.

Bridge with Upperbeam

► An upper boom (upperbeam) bridge can have significantly longer span lengths and withstand significantly greater loads. This bridge also has a trussed design. Strut braces, braces and statical triangles stabilize this bridge.



Task:

- **Build the upperbeam bridge.**
- **Place a load on the bridge in the middle.**
- **How has the stability of the bridge changed?**
- **Name all of the statical elements you know in the diagram: the upper boom, the strut braces, the braces and the supports.**

This bridge form can withstand bigger loads than the girder bridge. The compressive force is now transmitted not only to the girder, but is also distributed to the additional components. The upper boom consists of crossed diagonals, which are attached at the upper nodes of the side elements. The diagonals on the upper boom prevent the twisting of the bridge.

If the strut braces project upwards, then this bridge design is called a truss frame.

► Do you want even longer spans than are possible with the trussed designs? How about building a cable-stayed bridge? It is very long and looks great, but is it strong as well?

Cable-stayed Bridge



Task:

- Build the cable-stayed bridge.
- Add a weight to the left and right of the bridge's center pylon and compare its stability with that of the trussed designs.

So, how does the cable-stayed bridge stand up by comparison?

How is it possible for the bridge to be so strong and sturdy even though it is suspended only at the cables*? I'll tell you a secret: it is the cables and their arrangement that do the trick. The bridge consists of three main components: center pylons, steel cables and bridge deck. It has a high load capacity thanks to its clever design.

The vertical forces that drag the bridge deck downward are transferred by the cables to the center pylon, which transfers these forces to the ground.

This makes the cable-stayed bridge attractive as well as allows the bridge to span 1000 meters from pillar to pillar.

(* In your model struts fill the role of the cables.)

Crane

► You were able to gather experience from the areas of mechanics, levers and statics with the previous models. The final model will integrate this experience. The crane allows you to recognize the interplay of components and assembly groups and to test the statics for their load carrying capacity.

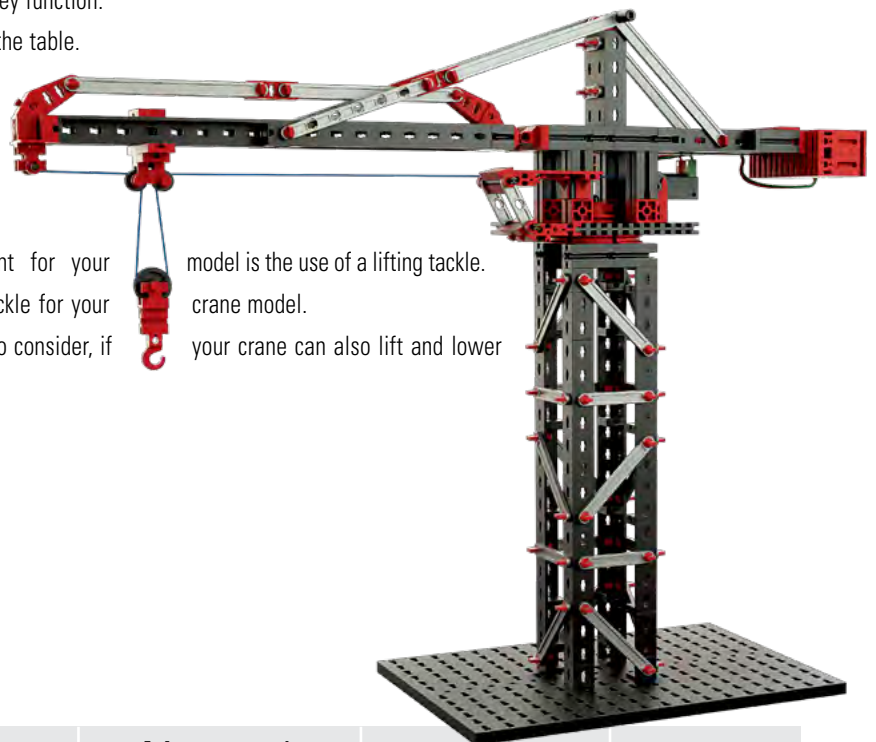
Task:

- **Build the crane as described in the assembly instructions.**
- **First assemble the fixed tower with its frame structure. Are you familiar with the structural elements that you are using? Write them down in the table.**
- **Next, build the boom with the turntable. The crane boom is a certain type of lever. How does the crane still maintain its balance? How is the boom stabilized? Fill out the table.**
- **What is the traveling carriage on the boom used for? Move it and observe what happens to the height of the hook.**



There are several types of gear units available for lifting weights.

- Install the possible gear units in your crane model.
- Compare the way they function.
- Enter the results in the table.



The crowning element for your model is the use of a lifting tackle.

- Develop a lifting tackle for your crane model.
- What do you have to consider, if your crane can also lift and lower very heavy loads?

model is the use of a lifting tackle. your crane can also lift and lower very heavy loads?

Assembly group	Advantages/ Peculiarities	Possible Uses	Components
Mechanics			
Statics			
Lever			