Class Set Statics – Primary level tasks

The Class Set Statics provides a low-threshold approach to important statics basics for teaching general science at primary level. The primary learning objective is static-constructive building and to sharpen the children's view of the static and constructive facts that surround them. Construction, research and reflection are encouraged in a playful and practical way. Working alone or in teams, pupils build simple models.

Learning objectives

- Content-related skills: Stability and strength in technical constructions, discovering correlations between load-bearing capacity and connection of construction elements, constructing buildings and load-bearing structures experimentally, getting to know functional features of load-bearing structures, trusses, system of beam and support, recognising the skeleton construction method in various structures in their environment, understanding compression and tensile forces, the system of triangular bracing, transferring features of a stable construction to a movable one, stability/balance, two-sided lever arm.
- Process-related skills: Problem-solving/ being creative.
- Mathematical skills: Logical and strategic thinking.
- Personal and social skills: finding a solution together in a team.
- Language communication skills: Development of specialist terms.

Time required

Individual topics should usually be able to be dealt with within one school lesson. The time required for experimenting, evaluation and discussion is estimated at approx. 45 minutes individually.

Name: ___________ Class: ___ Date: _________

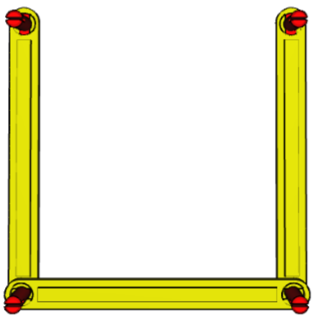
Model 1

Truss

We are going to build the "House of Santa Claus" using structural struts

Note: A so-called **member** is the simplest support in a structural system such as e.g. a truss or a frame. Members can be **linked** together by joints.

1. Start with the floor and the side walls:



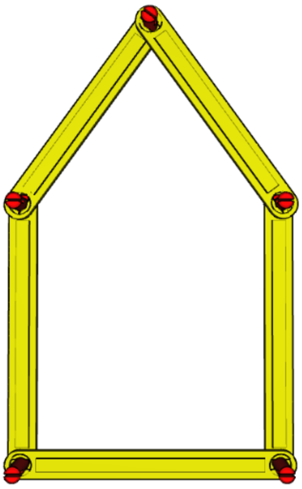
Test! Is the house wobbly or sturdy?

[ ] [ ]

The house is ____________. The three struts (truss members) are connected to one another by two joints and can freely rotate about these joints.

With a member in a chain, the respective adjacent member can be moved up and __________ or to the right or ________.

2. Build the roof and test:

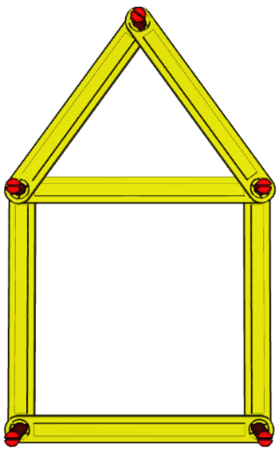


Is the house

wobbly or sturdy?

Together with the roof, the ______________________ now form a ______________ chain. However, the individual elements (members) can still move relatively freely. It's all still a bit wobbly, but less wobbly than the first try!

3. Install the "tie beam":



Is the house

wobbly or sturdy?

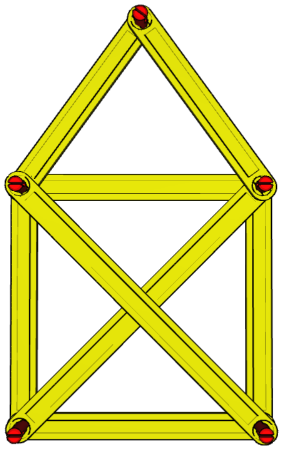
...or " a bit" sturdy?

The "tie beam" turns the roof into a closed triangle. The shape of the roof can

[ ] change
[ ] no longer change

The roof is ____________, the rest can still move quite easily.

4. Now all you need are the diagonals:



Is the house now

wobbly or sturdy?

...or " a bit" sturdy?

...or even very sturdy?

____

____

____

Yes, it's now finished: your "House of Santa Claus"!

5. The points where the members meet are also known as **nodes**. Do you know why the structure is so sturdy even though the nodes still have movable joints?

Name: ___________ Class: ___ Date: _________

Solution sheet model 1

Truss

1. The house is **wobbly**. The three struts are connected to one another by two joints and can freely rotate about these joints. With one member in a chain, the adjacent member can be moved up and **down** or to the right or **left**.

2. Together with the roof, the **truss members** now form a **closed** chain in which the individual elements can move relatively freely. It's all still a bit wobbly, but less wobbly than the first try.

3. The "tie beam" turns the roof into a closed triangle that can **no longer change** its shape. The roof is **sturdy**, the rest can still move quite easily.

4. The "House of Santa Claus" is now **extremely sturdy** – you could even leave one of the diagonal members out and it would still be sturdy.

5. The struts can rotate around the node axis in each node. But the node at the other end cannot move because it is "held tight" by the adjacent strut.

An ideal truss is made up only of members connected by joints. The load on these members is then only due to **tension** or **compression**.

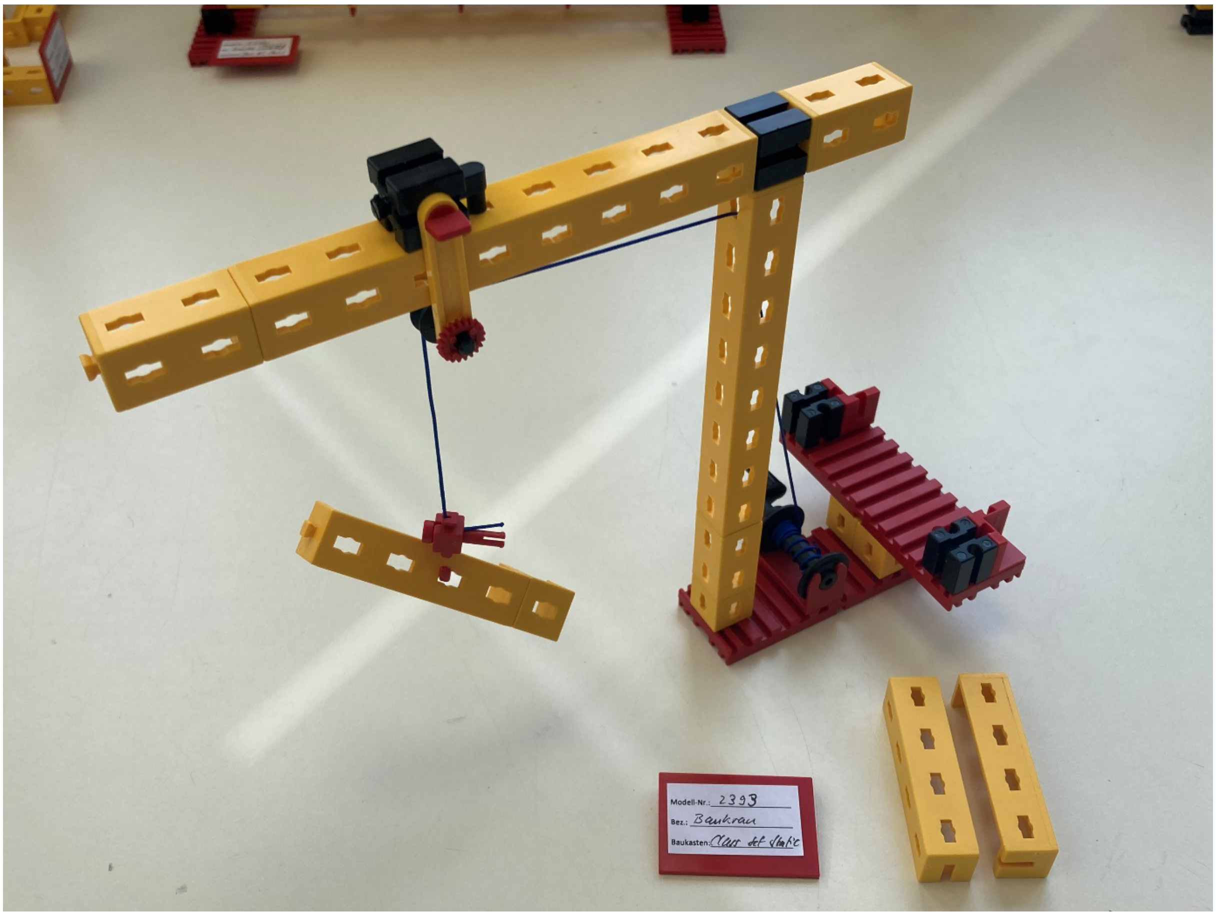
Name: ___________ Class: ___ Date: _________

Model 2

Crane

Construction task

Construct the crane according to the building instructions.

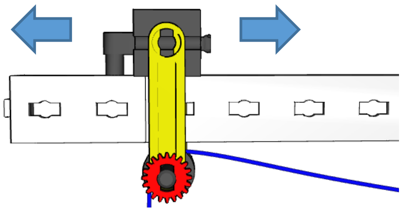


Topic tasks

Test the crane without the weights (2x angle girder 60):

Use the trolley* to slide the weight to be lifted (1x angle girder 60) right to the end of the jib:

*The trolley is the movable component on the jib that can be moved backwards and forwards.



Does the crane fall over?

If you fix the weights on the red plate at the rear of the crane – does the crane then remain upright when the load is suspended right at the front?

1. Try to explain why this is the case

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____

____

2. This results in the following findings:

The _________ the counterweight, the __________ the load that can be lifted.

The ___________ the load moves out, the ___________ the counterweight has to be to stop the crane falling over.

Experimental tasks

Test: when you crank a load upwards, you feel a slight counterforce in the crank.

Now let's do a few experiments:

1. Take a light and a heavy weight that the crane can lift. Hook the light weight onto the crane first, slide the trolley close to the tower and crank the weight right from the bottom to the top and back down again. Now slide the trolley as far out on the jib as possible and do the same again.

   What do you feel:

   Is the counterforce during cranking the same on both sides? Is it greater at the front? Is it greater close to the tower?

   ____

   ____

   ____

   ____

2. Do this experiment again with a heavy weight. Does the counterforce feel greater, the same or less than during the first experiment? If you compare close to the tower and the end of the jib again: Is the counterforce greater at the end, greater at the tower or the same at the end and at the tower?

   ____

   ____

   ____

   ____

Name: ___________ Class: ___ Date: _________

Solution sheet model 2

Crane

Topic tasks

1. When the counterweight is attached at the rear, larger weight can be lifted than when there is no counterweight in place. The reason for this is that the counterweight acts against the load on the crane or balances it. A load that is suspended right at the end of the crane jib needs more counterweight than a load in the middle or right at the beginning of the crane jib.

2. The **larger** the counterweight, the **heavier** the load that can be lifted.

   The **further** the load moves out, the **larger** the counterweight has to be to stop the crane falling over.

Experimental tasks

1./2. The counterforce in the rope on the crank is the same as the force at the end lifting the load. And this is true no matter how long the rope is. This is why it doesn't matter whether the load is at the end, in the middle or at the beginning of the jib. The force you need for cranking is the same everywhere.

When the crane is tilted, on the other hand, it does matter where the load is. If the weight of the load is too heavy, the crane might not topple over if the weight is suspended near the tower. When the load is moved away from the tower, the crane will topple over at some point before the end of the jib is reached. If it doesn't, the load is not too heavy.

Tip: the crane will not topple over, of course, if you hold it while cranking 😉

Name: ___________ Class: ___ Date: _________

Model 3

Lamp

Statics is not only relevant large machines or buildings, sometimes static problems have to be taken into account for small objects like a desk lamp as well. It is important that the lamp doesn't topple over.

Construction task

Construct the lamp according to the building instructions.

Topic task

Look at the model of the desk lamp. Nudge the lamp slightly with your finger from different directions.

1. What do you notice? Is it sturdy? Does it fall over easily in one direction?

From the **front**: [ ] sturdy [ ] topples over easily [ ] topples over very easily

From the **right**: [ ] sturdy [ ] topples over easily [ ] topples over very easily

From the **left**: [ ] sturdy [ ] topples over easily [ ] topples over very easily

From the **back**: [ ] sturdy [ ] topples over easily [ ] topples over very easily

2. What could the static problem of the lamp be?

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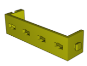
____

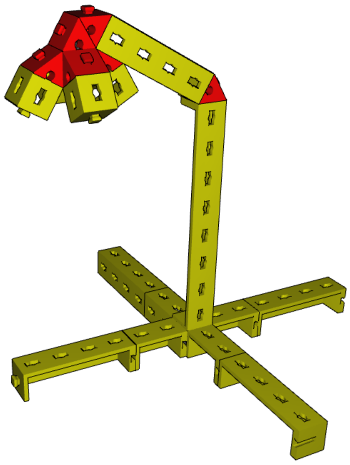
Experimental tasks

1. Take one of the longer angle girder (60, ) and fix it to each of the bases **in turn** and then repeat your "nudging experiment". In your opinion, which would be the best variant for the lamp if you only think about improving its steadiness?

[ ] Front? [ ] Back?

[ ] Right? [ ] Left?

2. Fix the long (60) angle girders to the short ones and carry out the "nudge experiment" again:



a) How sturdy is the lamp now? b) What is the disadvantage of such a large base on a desk lamp?

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____

3. Think about the optimum design for the lamp to ensure it doesn't topple over and is still practical. Build it and draw a sketch here:

Name: ___________ Class: ___ Date: _________

Solution sheet model 3

Lamp

Topic task

1.

From the front: [x] sturdy [ ] topples over easily [ ] topples over very easily

From the right: [ ] sturdy [x] topples over easily [ ] topples over very easily

From the left: [ ] sturdy [x] topples over easily [ ] topples over very easily

From the back: [ ] sturdy [ ] topples over easily [x] topples over very easily

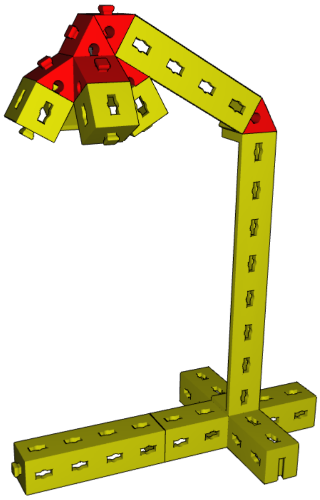
2. This is due to the weight of the lampshade. The weight is in front of the lamp base and exerts a force on the whole lamp, causing it to topple over forwards. It gets off-balance.

Experimental tasks

1.

[x] Front? [ ] Back?

[ ] Right? [ ] Left?



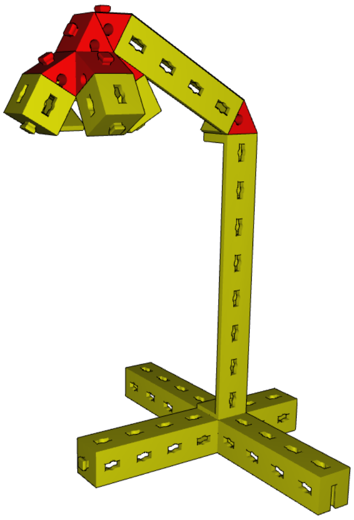
2. The lamp can hardly topple at all in the direction of the longer base and is sturdy in this direction.

   a) If the base is made long on all sides, the lamp can no longer topple over at all. It is now extremely sturdy.

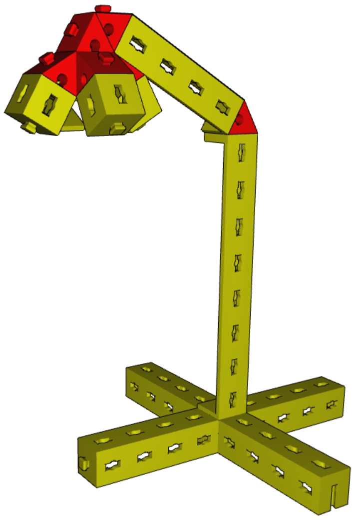
   b) However, it also becomes very wide and takes up a lot of space on the desk, which is very impractical. This is why it would be clever to lengthen the base on just one side – the one where the lamp topples over the easiest. At the same time, you can shorten the base at the back, since the weight of the lampshade counteracts toppling over backwards.

3. The question now is whether the practical variant is also the "pretty variant". A designer might say that all the bases have to be the same length, a structural engineer would say that the one at the back has to be short, the side ones medium and the front one long. In reality, we try to combine advantages and disadvantages and consider what is more important: Safety or design?

   So a good lamp would have bases that are longer but maybe not quite as long. Here are two examples that are good compromises ("quite right" is rare):



Practical variant

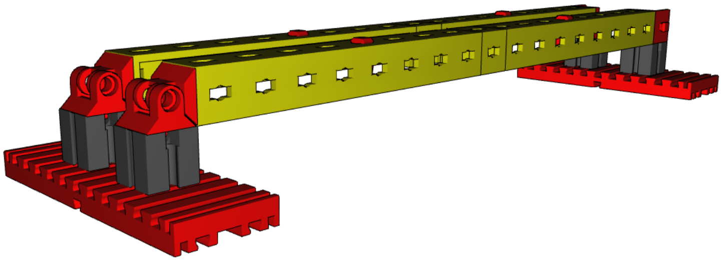


"prettier" variant

Name: ___________ Class: ___ Date: _________

Model 4

Bridge



Construction task

Construct the bridge according to the building instructions

Topic tasks

The beam bridge is the simplest bridge design. When a load acts on the bridge (e.g. vehicle, person), this load exerts a force on the bridge. Depending on how heavy the load is, the force on the bridge is greater or smaller. Thus the bridge is deformed to a larger or less extent. However, the point where the load is applied is also decisive for how much the bridge bends.

1. Try it out: Press onto the bridge at the far left, in the middle and at the far right:

   Where does it give the most?

   ____

   ____

   Where the least?

   ____

   ____

2. Now look at the bridge bearings (the “bases” of the bridge):

   When you press on the middle of the bridge, the bridge bases act in different ways. Can you see why?

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   ____

   ____

3. In your opinion, which of the bridge bearings works best? Why?

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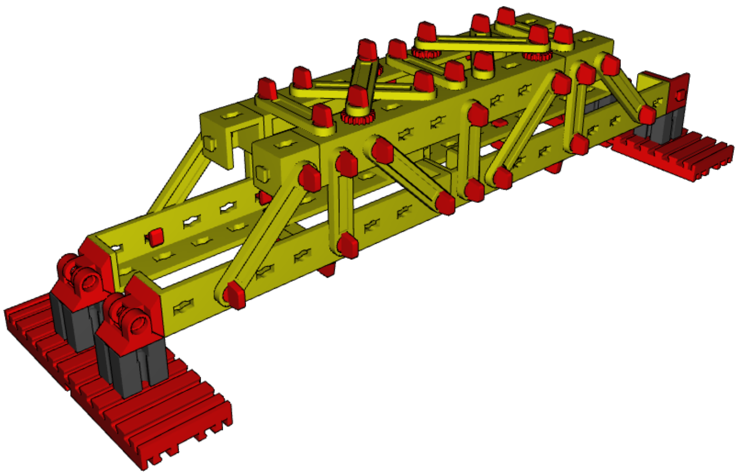
   ____

   ____

Experimental tasks

In the real world, you can never prevent structures from bending. Even the largest of bridges give a little, though not as much as your model bridge, of course. Now build a through truss on your bridge. This is a structure built over the bridge.



Repeat the same experiments:

1. Press onto the bridge at the far left, in the middle and on the right:

   Where does it give the most?

   Where the least?

   ____

   ____

   ____

2. Now look at the bridge bearings again. If you press just as hard in the middle of the bridge as in task 2 before, do the bases behave differently?

   ____

   ____

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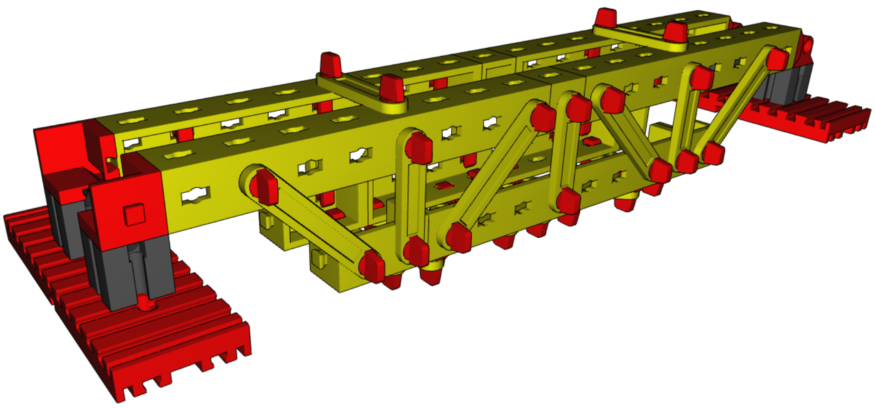
3. Now change the structure of the bridge as follows:



It's easy: all you have to do is swivel the jointed base and turn the other bridge bearing round. In this case, the truss structure is known as a deck truss. This type of bridge is suitable for railways to cross valleys. Take two books of the same thickness and set them down in such a way that you can connect them with the bridge.

4. Again, examine the reaction of pressure from above on the bridge.

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Name: ___________ Class: ___ Date: _________

Solution sheet model 4

Bridge

Topic tasks

1. The bridge bends the most exactly in the middle
   It does not bend at all directly above a bearing, since the entire force goes into the base and there is no load on the "beam" at all. This is true for both sides.
2. The base without a joint twists and lifts at the side.
   The base with the joint stays on the ground at first, because the joint can compensate the change in shape.
3. The jointed bearing works better. The structure does not become as deformed and the base is sturdy and remains on the ground. A real bridge base made of concrete would not "turn away", rather it would crack under such a deformation load.

Experimental tasks

1. The bridge still gives the most in the middle, but much less than before. It does not give at all at the bearing.
2. Now both bases remain flat on the ground, no deformation can be seen at the rigid bearing. Nevertheless, stresses still occur inside the structure, which we try to avoid in reality. For this reason, bridges (steel, wooden & concrete bridges) are usually mounted on joints on both sides. You can usually see this if you look closely.

(Source: Wikipedia)

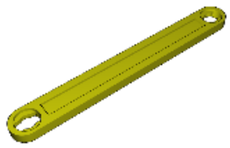
3. The bridge behaves in exactly the same way as the bridge with through truss. The deciding factor is not where the truss is, but how large and strong it is.

Name: ___________ Class: ___ Date: _________

Model 5

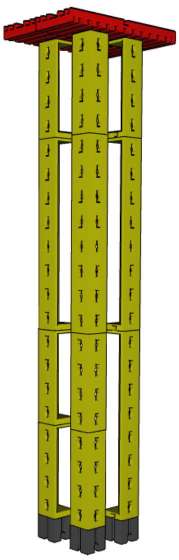
Tower

Construction task



First build the tower without the thin structural struts.

This is what it should look like:



Experimental tasks

1. Examine the tower: is it sturdy? Does it have a safe stance? Why do think this is the case?

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2. Hold the tower at the bottom using one hand and press the platform from different sides. Examine how the legs become deformed when pressure is exerted on the platform:

a) Deformed in relation to each other?

____

____

b) From top to bottom?

____

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c) To the front and back?

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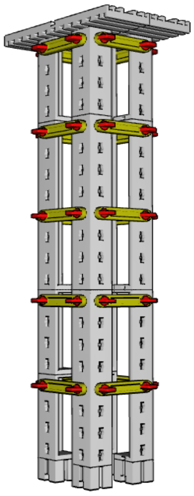
____

d) Do they rotate about their longitudinal axis?

____

____

3. Fit the horizontal struts:



Examine again how the legs become deformed:

a) Deformed in relation to each other?

___

___

b) From top to bottom?

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___

c) To the front and back?

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___

d) Do they rotate about their longitudinal axis?

___

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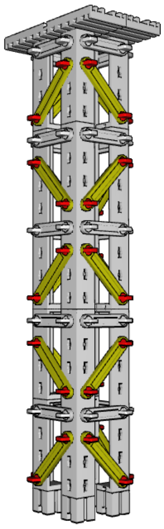
4. Now fit the diagonal struts



Examine again how the legs become deformed:

a) Deformed in relation to each other?

____

____

b) From top to bottom?

____

____

c) To the front and back?

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____

d) Do they rotate about their longitudinal axis?

____

____

Name: ___________ Class: ___ Date: _________

Solution sheet model 5

Tower

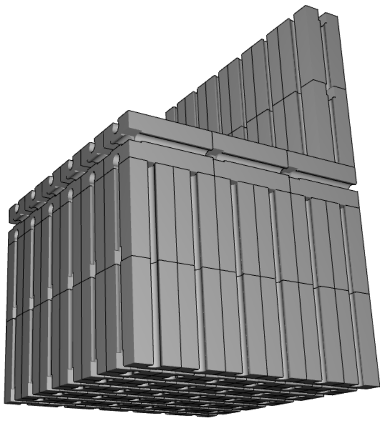
1. The legs are not sturdy. They are very long and thin, which is why they can move easily. The tower doesn't fall over, but it is very "wobbly".
2. Pressure on the platform from the side: the tower gives and moves out of the way.
   a) The legs become deformed in relation to each other.
   b) Pressure from above: The platform does **not** move downwards: the counterforce of the legs keeps the platform at the right height.
   c) The legs twist, the platform can be turned.
3. The tower is now extremely sturdy
   a) When pressure is exerted from the side (front / back) - the legs do not become deformed in relation to each another
   b) When pressure is exerted from above: The tower resists the pressure from above.
   c) The tower gives to the left and right if the force is not exerted onto the platform directly from above.
   d) The tower can twist about the longitudinal axis
4. a) No deformation in relation to each other
   b) No deformation downwards (with pressure from above)
   c) No deformation to the side
   d) No twisting about the longitudinal axis

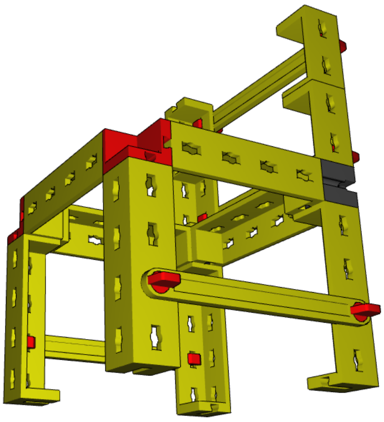
Name: ___________ Class: ___ Date: _________

Model 6

Chair

Statics always come into considerations when an object has to be **sturdy**. But stability is not the only reason. This is illustrated by the example of a chair:





1. If sturdiness is the only requirement, we could just cast a concrete chair in one piece. What are the disadvantages of a concrete chair?

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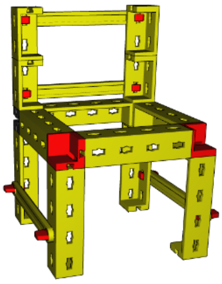
Construction task

Construct the chair according to the building instructions



Topic tasks

1. The chair in the building instructions has exactly the same shape as the "concrete chair" in task 1. Name the advantages of the "light chair".

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2. Name 3 functions the chair has to fulfil and check whether this model actually fulfils these functions.

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Experimental task

Consider what improvements can be made and test whether you can implement these with the parts you have available:

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Name: ___________ Class: ___ Date: _________

Solution sheet model 6

Chair

1. Disadvantages of a concrete chair:
   Weight: a concrete block of this size weighs more than 400 kg. You can't carry it round the house or push it back when you get up from the table, and it is sure to damage the floor in the dining room, too. It would also be difficult for furniture shops to transport this chair home for you, since you will usually need more than one: 4 chairs would then weigh as much as your car.

   Price: the manufacturer must make sure he uses as little material as possible for production, otherwise the chair will be too expensive. This is why a chair should not be a solid structural body.

   There are probably a lot of other disadvantages.

Topic tasks

1. Advantages of a light chair:
   - Light weight
   - Little material (so low price)
   - Still sturdy
2. Functions:
   - Useful: you have to be able to sit on it
   - Low price: you have to be able to afford it
   - Practical: you can move it easily

Experimental task

You could leave the structural struts off to save material. But then you have to test and see if it is still sturdy enough.

Name: ___________ Class: ___ Date: ________

Model 7

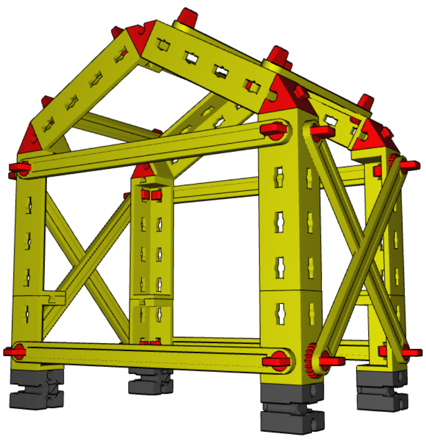
Truss building

There are buildings which are built of walls made of stone or concrete, they are made of steel – e.g. large factory halls or small metal garden huts. They often have a simple structure, which makes the building sturdy, and just thin metal walls, which hardly play any role in the stability of the building.

The structure which makes a building sturdy is also known as the structural frame. It is often made of members, the ends of which are linked to other members by joints, so that they form a cage: this is then called a “three-dimensional truss”. Buildings are often made up of “planar trusses” - the “House of Santa Claus” task is one such planar truss. In an ideal truss, the members only transfer tensile and compressive forces, which is very easy for engineers to calculate - and is why they like constructing buildings with a truss as the structural frame.

Construction task

Construct the building according to the building instructions

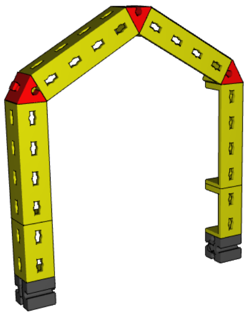


Topic task

1. Take a close look at the model of the truss building and consider which components at the front and back have a joint as support. In our example, we call these "structural struts". Count them on the picture and give each a number. How many structural struts does our building have?

   There are ____ structural struts in the building

2. There are two more large components in our building, which are made of several fischertechnik parts: the **bay rails**.

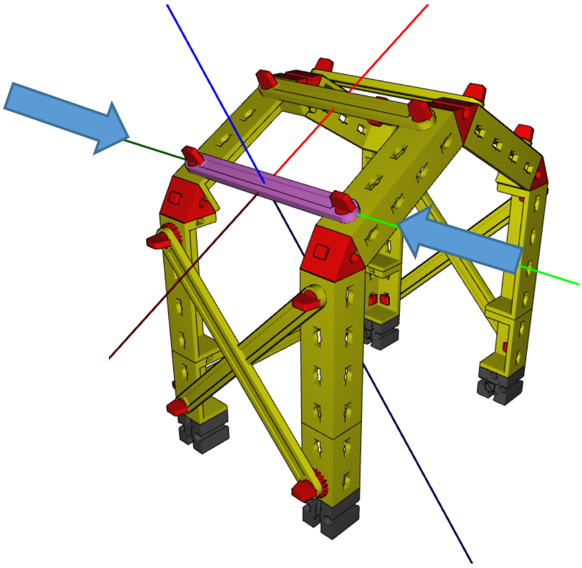


   Can you find them? They give the building its shape and are held in position by the structural struts. How many can you find in the model?

   There are ____ bay rails.

Experimental tasks

1. Now we are going to do experiments where we consider the function of the individual structural struts. Remove the bottom roof strut and then press onto the building from both sides. Exactly where the strut was:



a) What do you observe?

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b) Fit the strut again and test again. Describe the difference:

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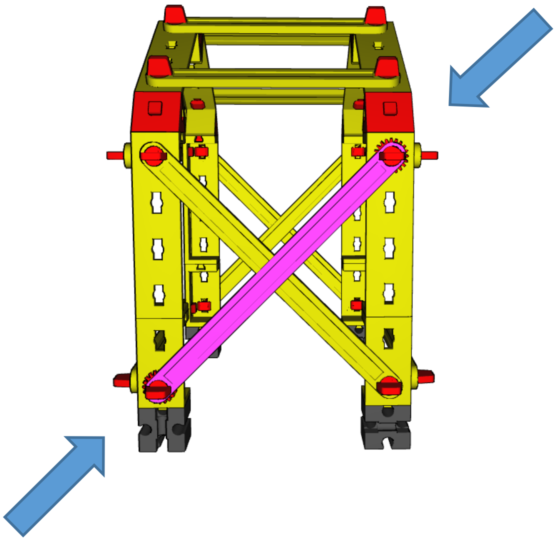
2. Do the same experiment with a diagonal strut:



a) What do you observe?

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____

b) Fit the strut again and test again. Describe the difference:

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3. What loads can act on the side of a building?

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4. What loads can act on a building from above?

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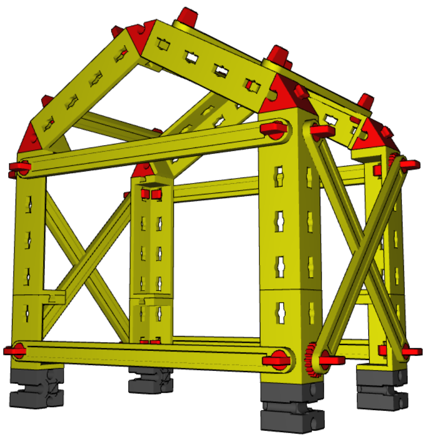
Name: ___________ Class: ___ Date: _________

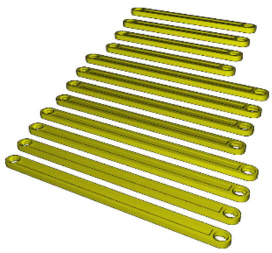
Solution sheet model 7

Truss building

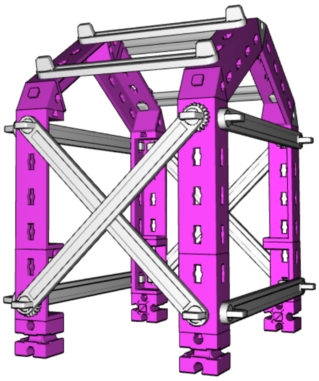


Topic task

1. There are 12 structural struts in the building.



2. There are 2 bay rails



Experimental tasks

1. c) The building is pressed together where the strut was.
   b) When the strut is fitted again, there is more resistance at this point, the shape of the building does not change.
2. a) The diagonal strut also ensures that the shape of the building does not change. When it is removed, the building gives at this point.
   b) When the strut is fitted again, the building no longer gives at this point.

3. Loads that can act on a building from the side are: Wind loads, moving loads or earthquake.
4. Loads that can act on a building from above are: Dead weight, snow, wind and moving loads. With roofs, the so-called “man load” is also considered: there must not be anywhere on the roof that cannot bear the load of a person, otherwise the roof can collapse it if is stepped on.

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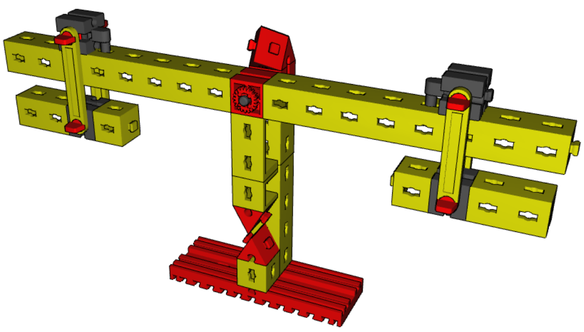
Model 8

The first-class lever



Construction task

Construct the first-class lever according to the building instructions. If you have built the model exactly, the pointers should point to each other exactly in the middle. The first-class lever is in equilibrium. (At the beginning, the pawl for the weight should be in the fourth hole from the outside.)

Topic task

1. Describe why the lever is in equilibrium:

____

____

____

____

2. Does it make a difference whether the weights are suspended straight down or at an angle?

____

____

____

____

Experimental task

1. Move the left-hand weight two holes further towards the middle (fulcrum) What do you observe?

____

____

____

____

2. Get the lever into equilibrium again by moving the right-hand weight.

   How many holes do you have to move the weight by, and in which direction?

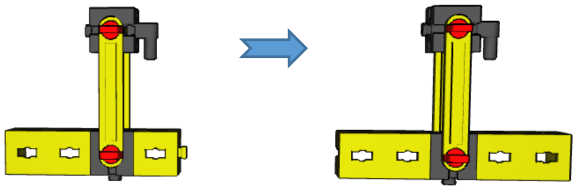
____

____

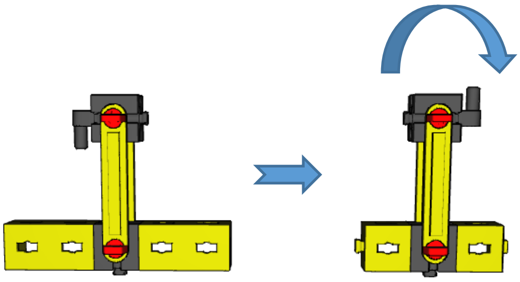
____

____

Rebuild the weight on the left-hand side using two angle girders 30:

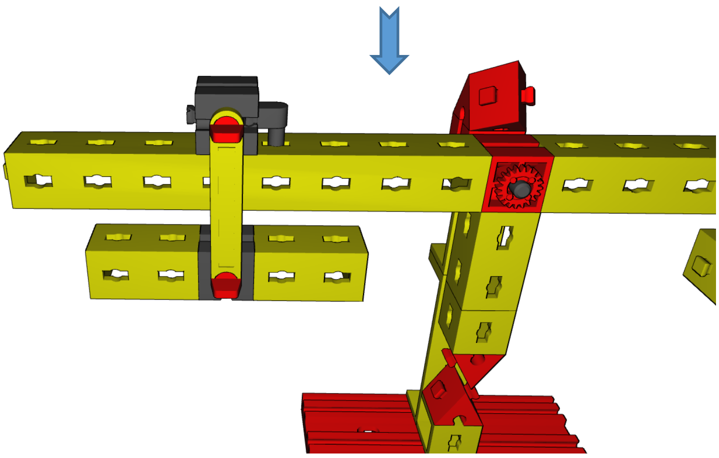


Then we change the weight on the right-hand side as well. Swap the two angle girders 30 for two angle girders 15, and turn the holder round so that the pin can no longer latch in place:



Now the weight can be moved freely on the right-hand side and does not latch into one of the holes.

Only position the left-hand weight in the 5th hole (seen from the end):



3. Now get the lever into equilibrium again by moving the right-hand smaller weight. Consider the distance of the smaller weight from the fulcrum. Is it smaller or larger than the distance of the left-hand weight?

[ ] smaller [ ] larger

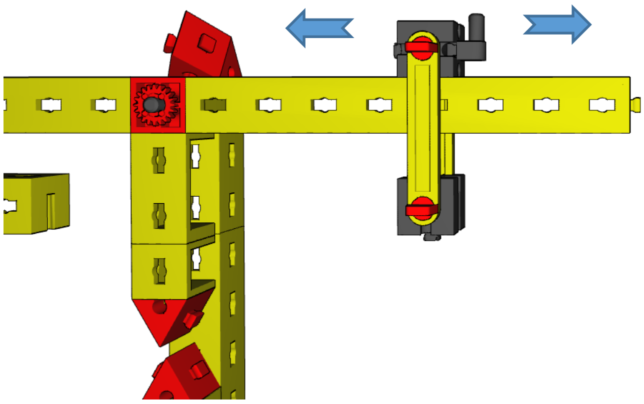
This observation can be used to create the following rule:

If the weight increases, the distance to the fulcrum has to be

___________ and if it decreases, the distance to the fulcrum has to be

___________ to compensate the counterweight and establish equilibrium.

4. Now do this experiment again without the yellow angle girders 15 and describe where the weight has to be:



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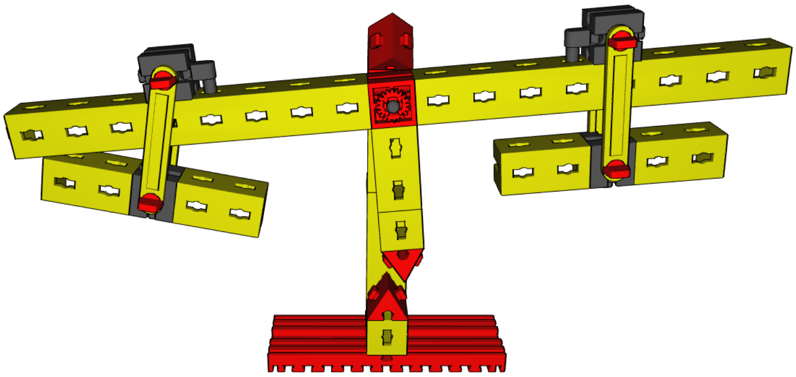
Solution sheet model 8

Lever

Topic task

1. The lever is in equilibrium because the **same weights** are suspended in the **same place** on both sides
2. Yes, it does: the lever lowers on the side where the weight has been "bent" outwards since the weight is no longer the same.



This can be compensated by bending the weight outwards on the other side as well.

Experimental tasks

1. The lever arm is raised on the left-hand side
2. The weight on the right-hand side has to be moved by two holes towards the lever arm as well.
3. [ ] smaller [x] larger

The distance of the right-hand weight has to be larger to establish equilibrium.

If the weight increases, the distance to the fulcrum has to be **decreased** and if it decreases, the distance to the fulcrum has to be **increased**, in order to compensate the counterweight and establish equilibrium.

4. The weight almost has to be right at the end of the lever to get the lever into equilibrium.