Simple machines – Primary level tasks

The Class Set Simple Machines provides a low-threshold approach to important mechanical basics and their physical effect for teaching general science at primary level. Everyday technical functions are constructed and explored in a playful and practical way and encourage reflection. Working alone or in teams, pupils build simple and more sophisticated machines, automatic machines, tools and physical models.

Learning objectives

- Content-related skills: Simple mechanisms with everyday relevance. Joints and hinges, pawls in many forms and applications, lever mechanisms, the event of levers, pivoting levers, several coupled levers, eccentrics, spring mechanisms, springs as an energy store, rope hoists and pulley, linear motions, scales.
- Process-related skills: Problem-solving/ being creative.
- Mathematical skills: Prenumeracy (sorting, ordering), 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.

Attachments
Simple machines

Further information

[1] Wikipedia: *Sliding door*, *Door handle*, *Door lock*, *Beam scale*, *Scales*, *Crane*. (Other types of crane are shown there as well), *Pawl*, *Toothed gears*, *Eccentric* , *Four-bar linkage* , *Linkage*, *Leaf spring* (in: *Spring*), *Slideway*

[2] Prof. Dr.-Ing. habil. Jürgen Dankert: *Planar quadrilateral linkage*.

Name: __________ Class: ___ Date: ________

Model 2

Garden gate

Construction task

Build the garden gate model according to the building instructions. Note:

- The building blocks 7.5 on the door frame and on the gate must be offset by 2 mm to each other so that the axle can be inserted from above.
- The gate should be able to glide smoothly into the door frame. Do not clamp it too tightly in the door frame.
- Leave the locking bolt (I-strut 45 in the middle of the door) off at first. It is not required in the first tasks.

Topic tasks

Without the locking bolt please:

1. Fit the gate: Hold it against the door frame accordingly and allow the axles 30 with the clips to slide into the axle bearings of building blocks 7.5 from above.

   Imagine this process with a "real", large gate. What could be difficult?

   ____

   ____

   ____

2. The two axles 30 with the clips and the matching axle bearings are also called

   ___________ on a real gate.

3. Close the gate and imagine that a burglar has come and wants to lever out or unhinge the gate. Why does this not work and what is the name of the component that prevents this?

____

____

Now fit the locking bolt to the gate:

4. Close the gate "quietly" by lifting the locking bolt as you close it and then closing the door. The bolt holds the gate in the frame as long as it is closed. This simple type of lock is often used on garden gates.

What do you have to do to open the gate?

____

____

5. Now close the door "loudly" by "slamming" it shut without lifting the locking lever. Why does that work?

____

____

____

Experimental task

1. How can you open this garden gate?

   [ ] 90° [ ] 180° [ ] 360°

2. Press the clips of the locking bolt tightly together so that the locking bolt can no longer be moved easily. What do you observe when you only "slam" the gate shut?

   ____

   ____

   ____

3. What kind of weather could lead to a locking bolt on a real garden gate no longer being easy to move?

   ____

   ____

4. What could you do with a real garden gate if the locking bolt is no longer easy to move?

   ____

   ____

Attachments
Garden gate

Further information

[1] Wikipedia: Door handle.

Name: ___________ Class: ___ Date: _________

Model 3

Room door

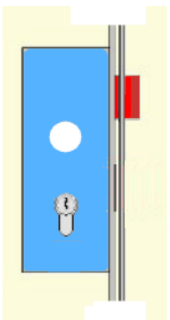
Note: The construction of the side of the door frame with the hinge pivot/hinges is the same as for the "garden gate" model and can be reused. The hinges on the door leaf are the same, too. The rest of the frame and the mechanism on the door are constructed in a different way than for the garden gate, however.

Construction task

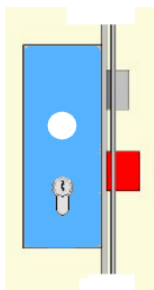
Build the room door model according to the building instructions. Note:

- The building blocks 7.5 of the door hinges must be offset by 2 mm to each other so that the axles can be inserted from above.
- The link 15 on the rear of the mechanism, which is connected to the door handle at the front, has to project a little way out of the building block 7.5.

Memorise these terms: The **door handle** is the element you have to press down to open the door. It moves the so-called **falling latch (latch)**, which engages with the striker plate of the door frame when the door is closed.



Falling latch or latch



Bolt

The **bolt** is a general term for the component that blocks the door when it is locked; it can be realised in many different ways.

It makes no difference whether the bolt is activated by a lock or pushed forward, closed, swivelled or hooked into place (garde gate).

The bolt can be a loose bar, a screwed-on hook or a slidable bolt, or a moving component of different types in a lock.

Topic tasks

1. Hold the door open and press the door handle (the red link 15 on the front of the door). Try to describe what happens in individual steps during the mechanical process of pressing the door handle.

   Follow the path of the force exerted on the door handle by the rotatable axle to the rear of the door. This is where the movable door "bolt" can be found.

   a) When the door is opened, the door handle is pressed ____________

   b) This makes the axle of the door handle turn _________. (Seen from the front)

   c) On the rear of the door, building block 7.5 with link 15 not quite inserted completely turns _________.

   d) The link 15 ___________ the door bolt (the two angle girders 15 and the angular block 30° attached to these)

      [ ] away from the door frame.

      [ ] into the door frame

   e) This causes the spring (I-strut 45) to be _________.

   f) When the door handle is released, the _________.causes the door bolt to be pressed back into the ___________.

2. Sometimes our self-built door might be able to be pulled open without the door handle being pressed. Which component has to be adjusted to stop this happening?

   If the door opens so easily, the ______________________ must be moved further to the ________ in the direction of the door frame. The spring must press the angular block 30° reliably into the striker plate (the angle girder 30 in the door frame).

3. Close the door "loudly" by "slamming" i.e. without pressing the door handle down.

a) Why does that work? Take a look at the door latch on the classroom door.

That works because the angular block 30° meets the door frame ___________.

b) Imagine our door cannot simply be pressed closed because the door bolt does not engage with the striker plate (angle girder 30 in the door frame) properly:

In this case, the ______________________ must be moved further to the _________.

Experimental tasks

1. Move building block 15 with the spring-loaded I-strut 45 on the rear of the door to cause the problems described in topic tasks 2 and 3. What conclusions do you draw?

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____

2. Find the position in which the door closes cleanly with the help of the door handle, but at the same time can simply be pushed shut smoothly.

3. Remove the red flat “building block 15x30x5 with groove and pin” from the last construction step of the instructions on the rear of the door. Why does the door now no longer work properly?

____

____

____

Attachments
Room door

Further information

[1] Wikipedia: Door handle.

Name: ___________ Class: ___ Date: _________

Model 4

Beam balance

Note: As well as fischertechnik parts, the weights of other small objects can be compared using the balance.

Construction task

Build the beam balance model according to the building instructions. Note:

- The balance must pivot smoothly at the top.
- The two pans are mounted so that they can pivot. This movement must also be smooth. For this reason, do not press the clips too closely together. The clips can also be moved out a little by turning and pulling slightly.

Topic tasks

1. Place various spare fischertechnik components, coins or other small objects in the two pans. What do you observe when one side holds components that are heavier than the other?

   The beam of the balance tilts to the side. The ___________ part is further _________. The pan with the __________ weight is raised.

2. What happens when both pans hold components of the same weight?

   If the parts in the two pans weigh the same, the beam of the balance aligns

   ___________.

3. What could the purpose of the two struts with the structural rivet be on the top of the balance?

____

____

____

4. We can use a beam balance to quickly find the **equilibrium** of objects. Can a beam balance also be used to measure the weight of objects, although it does not have a scale?

____

____

____

Experimental tasks

1. Place two objects of equal weight into the pans e.g. one fischertechnik building block 30 each. Move one of these as far to the inside of the pan as possible and the other as far to the outside.

   a) What do you observe?

   ____

   ____

   b) So what do you have to take into account?

   ____

   ____

2. Press the clips of one of the two pan supports firmly inwards, so that this pan can no longer move freely. Place a building block 30 in each pan. What happens?

____

____

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Attachments
Beam balance

Further information

[1] Wikipedia: Beam balance.

Name: ___________ Class: ___ Date: _________

Model 5

Sliding balance

Note: As well as fischertechnik parts, the weights of other small objects can be compared using the balance.

Construction task

Build the sliding balance model according to the building instructions. Note:

- The clips must not be too tight against the components, so that all parts can move smoothly. This affects the upper balance beam support, the pan support and the support for the small weight underneath the slidable red building block 15 with bore.
- The small spacer ring 3 mm in the middle of the upper balance beam support (between the column and the balance beam) also contributes to smooth running - don't forget to insert this.

Topic tasks

1. Release the pan and move the so-called running weight or balance weight in such a way that the balance is in equilibrium. The fact that the S-rivet on the bottom of the pointer is aligned exactly with the S-rivet on the column of the balance shows that this is the case.

   There is one point to which the balance weight must be moved to get the balance into equilibrium.

   If you move the balance weight _______ to the fulcrum, the pan is lowered. If the balance weight is moved further away from the fulcrum, the pan _________.

2. Place a fischertechnik building block 15 in the pan. Now which direction do you have to move the balance weight in to get the balance into equilibrium??

   [ ] the weight must be moved away from the fulcrum

   [ ] the weight must be moved closer to the fulcrum

Kommentiert [AL1]: Muss Waagschale heißen

3. Repeat the same experiment using a building block 30. What do you find?

   [ ] the weight has to be moved even further out

   [ ] the weight must be moved closer to the fulcrum

   The __________ the weight placed in the pan, the further the balance weight has to be moved _________.

Experimental tasks

1. Place a building block 30 in the pan and get the balance into equilibrium. Use a ruler to measure the distance of the balance weight from the balance fulcrum and note down this distance. If you don't have a ruler, count how many holes there are in the horizontal beam of the balance between the fulcrum and the balance weight. Note the result for task 2.

   Distance ___________ cm or _________ holes

2. Hold the balance weight exactly in the position noted in task 1. Now fill the pan with other weights (fischertechnik parts or other small parts) until the balance is in equilibrium again.

So if the position of the balance weight is not changed, we can measure whether weights of different objects...

[ ] are the same

[ ] are heavier

[ ] are lighter

In task 1, we used building block 30 to ____________ the weight to be measured by the sliding balance.

Name: ___________ Class: ___ Date: _________

Model 6

Crane

Note: To be able to hang something onto the crane hook, a standard household rubber band is handy.

Construction tasks

The topic tasks refer to the crane in various stages of expansion:

First build the crane without the "tower" (the base on which the crane can slew) and without the pawl (the building blocks 7.5, which engage with the gear wheel Z10) according to the instructions.

Tasks 2 also use the pawl.

Tasks 3 adds the block and tackle.

Tasks 4 add the tower (base) below the crane

Topic tasks

1. Wind the crane rope up by turning the red gear wheel Z20. You can turn it in two directions to wind the rope up. For the following tasks, however, it is important that you turn it so that the rope runs to the crane arm from the bottom of the rope drum, not from the top.

   a) When the rope has been wound up so that the crane hook is almost at the top (underneath the rope pulley), hold the black base plate 120x60 tight and pull the crane hook down. What happens? Why would that be bad for a crane?

   ____

   ____

b) Alternate between turning the red gear wheel Z20 and the back gearwheel Z10 or the crank. What do you observe?

____

____

c) Adjust the inclination of the crane arm by fastening both S-rivets of the structural struts in different holes on the crane arm. What can you achieve with this?

The flatter the angle of the crane arm, the

____

____

The steeper the angle of the crane arm, the

____

____

2. Now add the pawl. It must be resting on the top of the gear wheel Z10. Repeat the task from above and pull on the crane rope. What happens? Which direction can the crane rope still move freely in? What do you have to do to lower it?

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3. In task 1. b) you could see that the rope is wound up or unwound more slowly when you turn the crank rather than the rope drum directly. **Now add the "pulley".** What do you observe now when you turn the crank? So what is the advantage of the pulley?

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4. Now add the "tower" below the crane platform. This allows the crane to lift things from further up, and you can slew the crane yourself.

   a) What happens when the weight hooked onto the crane is too heavy?

   ____

   ____

   ____

   b) What difference does it make to this whether the crane arm is flat and projecting a long way out or projecting less far out?

   ____

   ____

   ____

Experimental tasks

1. If components are left over, you can extend the "bases" of the crane tower. What difference does it make if you lengthen the bases "forward" (towards the crane hook) to increase stability?

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2. What difference does it make when you lengthen the bases "backward" (at the rear of the crane)?

____

____

____

Attachments
Crane

Supplementary material

- A household rubber band or other string can be useful to attach objects to the crane hook.
- Any kind of objects – fischertechnik parts, pens, whatever - can be lifted using the crane.

Further information

[1] Wikipedia: *Crane*. (This article presents other types of crane as well.)

[2] Wikipedia: *Ratchet*.

Name: ___________ Class: ___ Date: _________

Model 7

Ball passing 1 - Rotary lever

Note: You need at least one table tennis ball. You can use several at the same time, however, especially when several ball passing modules are built up connected to one another.

Construction task

Build the model ball passing 1 according to the building instructions. Tip: The track always looks the same, but the mechanisms for moving the table tennis ball differ from one model to another.

Topic tasks

1. Place a table tennis ball at the entrance (the shorter part of the track) and turn the crank clockwise (to the right). Observe how the rotary levers pick the ball up and lift it over the hill. What happens when you turn the crank in the opposite direction?

   ____

   ____

   ____

2. If several modules are built up at the same time, connect them to form a longer track! All you have to do is insert the pins of building block 15 at the

end of the module into the grooves of building block 15 at the entrance to the next module.

Experimental tasks

1. How often do you have to turn the crank for the levers (both) to rotate once? Try to describe what happens and why.

   Tip: the small black gear wheel has 10 teeth and the red gear wheel has 20.

   ____

   ____

   ____

   ____

2. How many balls can be lifted when the crank moves through one revolution? Why do you not need two revolutions of the crank for one ball?

   ____

   ____

   ____

   ____

Attachments
Ball passing 1 - Rotary lever

Supplementary material

- Table tennis balls

Further information

[1] Wikipedia: *Gear*

Name: ___________ Class: ___ Date: _________

Model 8

Ball passing 2 - Four-bar linkage

Note: You need at least one table tennis ball. You can use several at the same time, however, especially when several ball passing modules are built up connected to one another.

Construction task

Build the model ball passing 2 according to the building instructions.

Topic tasks

1. Place a table tennis ball at the entrance (the shorter part of the track) and turn the crank clockwise (to the right). Observe how the gear wheel lifts the lever above the I-strut 45 and lowers it again, thus lifting the ball over the hill.

   We have a combination of two types of gear in front of us:

   a) An "eccentric gear"

   The axle with the I-strut 45 inserted in the gear wheel turns

   [ ] outside the centre of the gear wheel

   [ ] inside the centre of the gear wheel

   This leads to a back-and-forth or up-and-down movement of the I-strut 45 away from the centre axle (axis of rotation) of the gear wheel. This type of movement is called eccentric.

b) A "four-bar linkage"

Find the four rotating joints on the model, which are all connected to one another by lever:

1. The centre of rotation of the gear wheel with the crank,
2. the axle in the gear wheel with the rotating mounted strut (the "lever" here is the gear wheel itself),
3. the rotating mount of the top of the strut in the long lever
4. as well as the rotating support of the large lever at the model exit.

2. If several modules are built up at the same time, connect them to form a longer track! All you have to do is insert the pins of building block 15 at the end of the module into the grooves of building block 15 at the entrance to the next module.

Experimental tasks

1. How many balls can one revolution of the crank lift?

____

____

2. What is the angle girder 30 hanging downwards on the end of the lever for? What can happen if you leave this off?

____

____

____

Attachments
Ball passing - Four-bar linkage

Supplementary material

- Table tennis balls

Further information

[1] Wikipedia: *Eccentric*.

[2] Wikipedia: *Four-bar linkage*.

[3] Wikipedia: *Mechanical linkage*.

[4] Prof. Dr.-Ing. habil. Jürgen Dankert: *Planar quadrilateral linkage*.

Name: ___________ Class: ___ Date: _________

Model 9

Ball passing 3 – Launcher

Kommentiert [AL1]: ??

Note: You need at least one table tennis ball. You can use several at the same time, however, especially when several ball passing modules are built up connected to one another.

Construction task

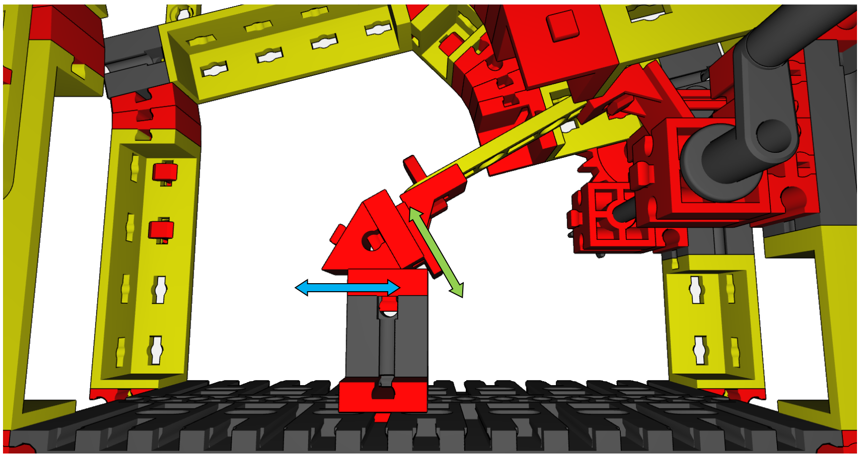
Build the model ball passing 3 according to the building instructions. Observe the following points:

- All four building blocks 7.5 which the axle with the crank is attached to, have to be moved as far up as possible in the building blocks 30 so that the black gear wheel Z10 can engage cleanly with the red gear wheel Z20.
- The red link 15 must be fitted cleanly in the centre in clip adapter 20.

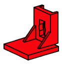
The "railing" is required for this model to stop the ball jumping out of the track to the left or right. It can also be attached to the three other ball passing models, but is not necessary on these.

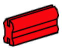
Topic tasks

1. Place a table tennis ball at the entrance (the shorter part of the track) and turn the crank clockwise (to the right). You have to set ("adjust") the mechanism at two points for it to work perfectly.



You can move the angular block 60°  (**blue arrow**) forwards or backwards in the model (to the right or left on the diagram) on building block 5 underneath.

The structural adapter girth  (**green arrow**) which the I-strut 45 is attached to, can be moved up or down. Start with the position shown on the diagram.

The rotating red link 15  must press the pin of the structural adapter girth at the end of the strut from the top downwards.

Adjust the mechanism in such a way that the table tennis ball bounces reliably over the hill but not higher than the railing.

Can you describe how the model works in your own words?

2. If several modules are built up at the same time, connect them to form a longer track! All you have to do is insert the pins of building block 15 at the end of the module into the grooves of building block 15 at the entrance to the next module.

Experimental tasks

1. How often do you have to turn the crank for the link 15 to rotate once? Why is that, what happens here?

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2. How many balls can be lifted when the crank moves through one revolution? Why do you not need two revolutions of the crank for one ball?

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____

Attachments
Ball passing - Launcher

Supplementary material

- Table tennis balls

Further information

[1] Wikipedia: *Leaf spring* (in: *Spring*).

Name: ___________ Class: ___ Date: _________

Model 10

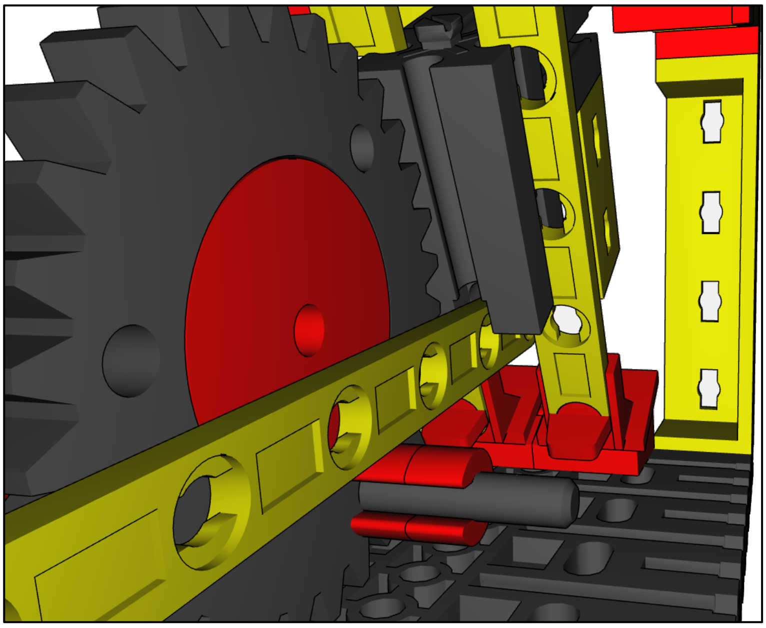
Ball passing 4 – Linear feed

Note: You need at least one table tennis ball. You can use several at the same time, however, especially when several ball passing modules are built up connected to one another.

Construction task

Build the model ball passing 4 according to the building instructions. Observe the following points:

- The building block 30 must slide easily between the two structural struts, but be guided safely. For this, the strut supports must be approx. 1 mm apart at the base.
- The building block 30 should be placed between the struts in such a way that the groove on its underside is aligned along the model.
- The horizontal prone strut should engage in the lower groove of the building block 30. The strut must be above the axle with the clip inserted in gear wheel Z30:



Topic tasks

1. Place a table tennis ball at the entrance (the shorter part of the track) and turn the crank clockwise (to the right). Describe briefly how rotating the crank leads to the ball being lifted.

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____

____

2. If several modules are built up at the same time, connect them to form a longer track! All you have to do is insert the pins of building block 15 at the end of the module into the grooves of building block 15 at the entrance to the next module.

Experimental tasks

1. How often do you have to turn the crank for one ball to be lifted?

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____

____

2. Compare the speed of movement of the "lift"

   a) during upward and downward movement and

   b) if you change the direction of rotation of the crank.

   Can you see what happens and why?

____

____

____

____

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Attachments
Ball passing - Linear feed

Supplementary material

- Table tennis balls

Further information

[1] Wikipedia: *Slideway*.

Name: ___________ Class: ___ Date: _________

Model 11

Ball passing - Group model

The four ball passing models suggested are ideally suited for a final project carried out together by the whole class:

The modules can be connected directly to one another by the pins of building blocks 15 at the exit of the modules being inserted into the corresponding grooves on the building blocks 15 at the entrance to the next module.

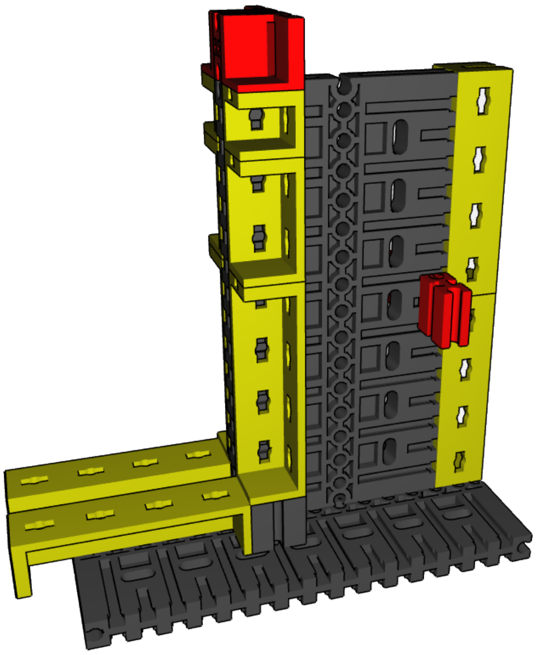
- We recommend connecting the modules in such an order that the side the cranks are on alternates. This allows the children to sit on both sides of one or more desks and the children more room at "their" crank.
- The numbering order of the modules (1. Rotary lever, 2. Four-bar linkage, 3. Bouncer, 4. Linear feed) is suitable in this sense, for example.

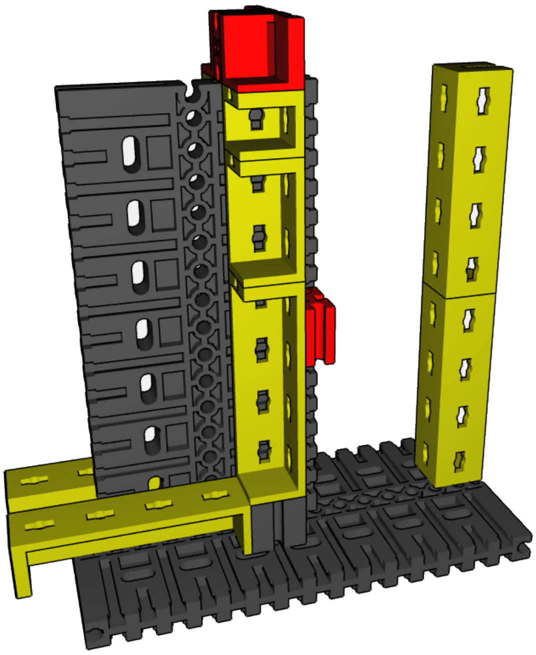
You need at least one table tennis ball. You can use several at the same time, however, especially when several modules are built up connected to one another.

Name: ___________ Class: ___ Date: _________

Solution sheet model 1

Sliding door





Topic task

1. When the door is slid open by the handle, the door **disappears** between the vertical girders – where the wall would be in a building.
2. This means the wall has to be hollow! The **cavity** in the wall must be at least as big as the door so that it can slid completely into it.

Experimental task

Without the handles it is difficult to get the wall out of the door again. For this reason, some doors have another pulling possibility on the narrow side of the door leaf (the one you look at when the door is completely open).

Attachments

Sliding door

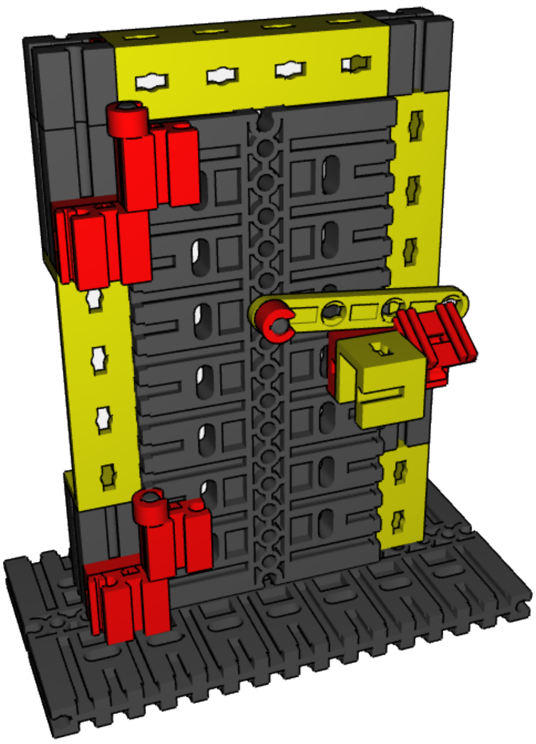
Further information

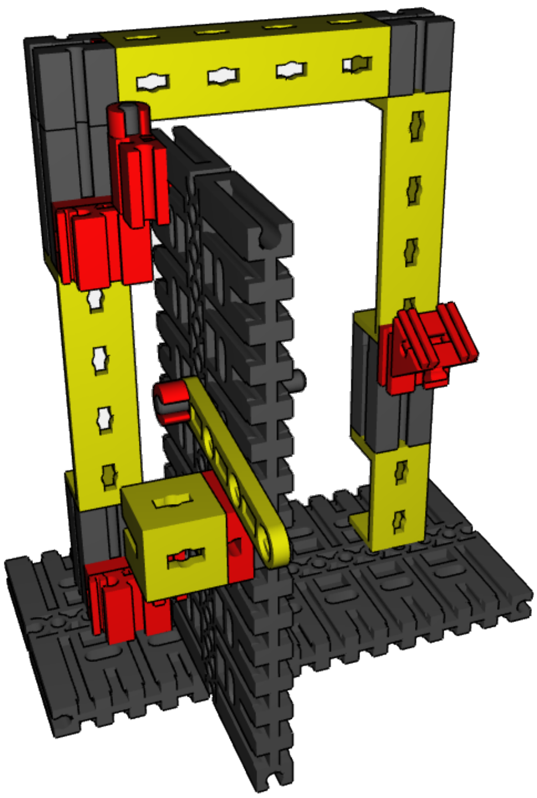
[1] Wikipedia: Sliding door.

Name: ___________ Class: ___ Date: _________

Solution sheet model 2

Garden gate





Topic task

1. A "real" door is heavy. You still have to hold it straight so that both axle bearings are aligned and can be slid into place at the same time. The best way to do this is to work with another person!
2. Hinge pivot
3. When the gate is closed completely, part of the door leaf is within the **door frame**. The **door frame** prevents the door being lifted up and out. This is why a burglar cannot simply open it by lifting it up when it is closed.

4. To open the gate, you have to lift the locking bolt first, so that it can be moved above the top edge of the lock.
5. The lock has been built at an angle on purpose, so that the locking bolt can fall slide up the angled surface and into the lock from above simply by pushing the gate closed.

Experimental tasks

1. 180°
2. A locking bolt that is not easy to move will not fall into the lock by itself. You have to press the locking bolt down with your hand to close it.
3. **Rain** could cause a locking bolt made of metal to rust and make the mechanism stiff.
4. The mechanism can be made smooth-running again by cleaning and lubricating/oiling if necessary.

Attachments

Garden gate

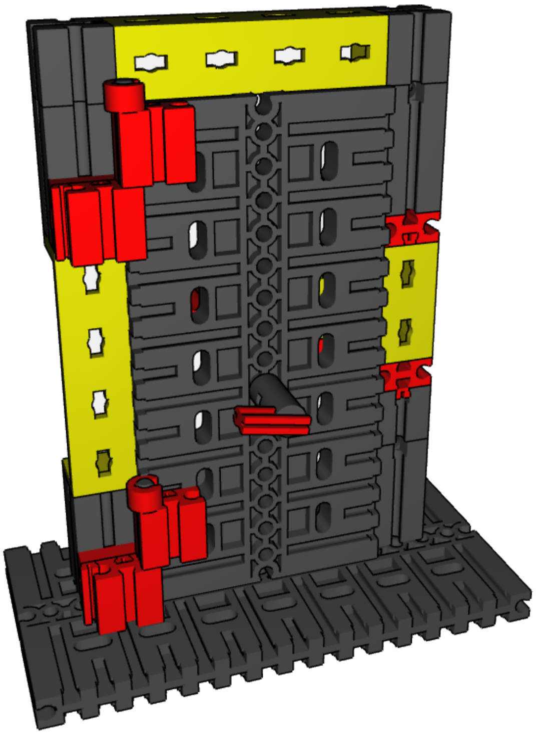
Further information

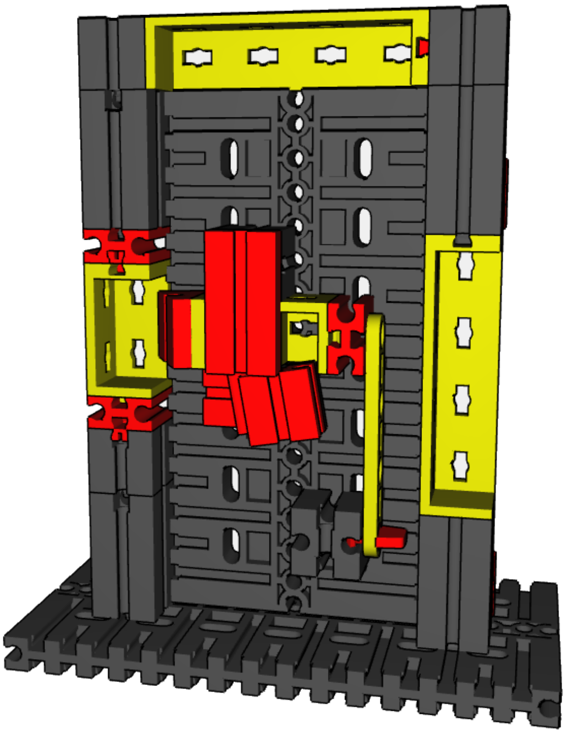
[1] Wikipedia: Door handle.

Name: ___________ Class: ___ Date: _________

Solution sheet model 3

Room door





Topic task

1. The mechanical process:

   a) When the door is opened, the door handle is pressed **down**

   b) This makes the axle of the door handle turn **anti-clockwise**. (Seen from the front)

   c) On the rear of the door, building block 7.5 with link 15 not quite inserted completely turns **clockwise**

   d) The link 15 **pushes or presses** the door bolt (the two angle girders 15 and the angular block 30° attached to these)

[x] away from the door frame.

[ ] into the door frame

e) This causes the spring (I-strut 45) to be **pressed or tensioned**

f) When the door handle is released, the **spring**.causes the door bolt to be pressed back into the **door frame**.

2. If the door opens so easily, the **building block 15 with the spring** must be moved further to the **left** in the direction of the door frame. The spring must press the angular block 30° reliably into the striker plate (the angle girder 30 in the door frame).

3. "Slamming" the door:

   a) That works because the angular block 30° meets the striker plate (angle girder 30) **at an angle**. This means it can slide in when pressed.

   b) Then the **building block 15 with the spring** must be moved further to the **right**.

4. To open the gate, you have to lift the locking bolt first, so that it can be moved above the top edge of the lock.

5. The lock has been built at an angle on purpose, so that the locking bolt can fall slide up the angled surface and into the lock from above simply by pushing the gate closed.

Experimental tasks

1. If the spring is adjusted too far to the right, the door bolt cannot engage at the striker plate (angle girder 30) of the door frame. If it is adjusted too far to the left, it presses to hard and the door can either not be closed at all or only with the door handle.

2. As is often the case, there is an optimum position in which the door works best...

3. Without the "bolt housing" the door bolt would not be held in place and could fall out. Worse even: The door could simply be pushed open!

Attachments

Room door

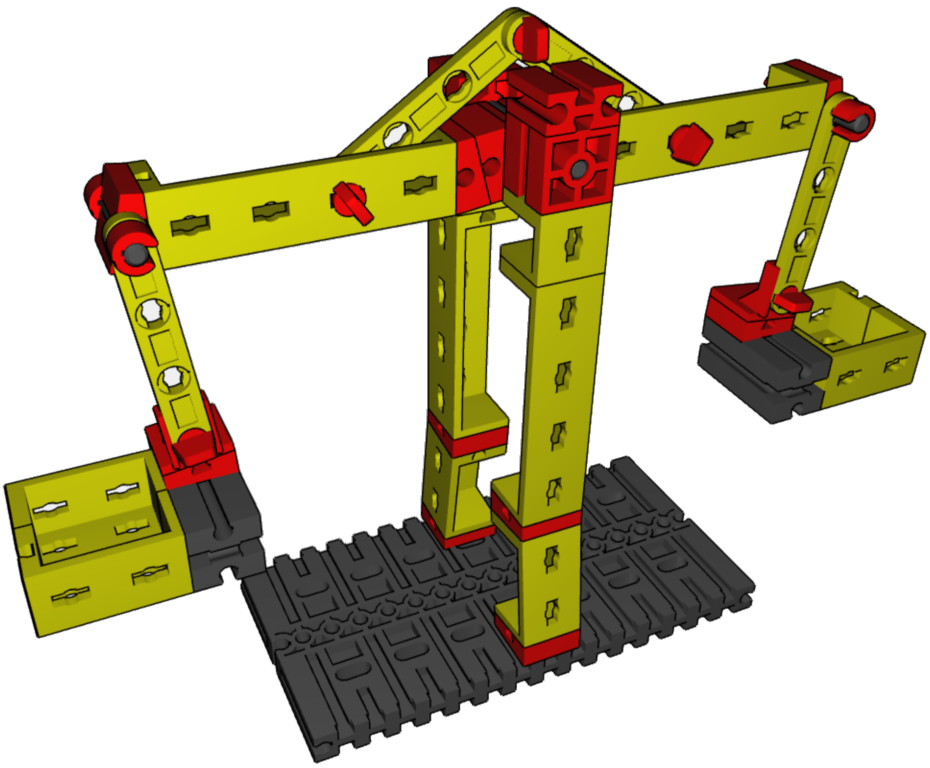
Further information

[1] Wikipedia: Door handle.

Name: ___________ Class: ___ Date: _________

Solution sheet model 4

Beam balance



Topic tasks

1. The beam of the balance tilts to the side. The **heavier** part is further **down**. The pan with the **lighter** weight is raised.
2. If the parts in the two pans weigh the same, the beam the balance aligns **horizontally**
3. The structural rivet and the fixed building block 7.5 serve to be able to read off exactly when the balance is in “equilibrium”, in other words when the same load acts on both sides.

4. We can use the balance beam to check of two weights weigh the same. The object to be weighed is placed in one of the pans and the other pan is filled with **known weights** until the balance is in equilibrium.

   The weight determined is the sum of all the known weights placed in the second pan. However, the beam balance does not have a scale where we can read off the weight of an object directly

Experimental tasks

1. If both pans contain the same objects, but these are at different distances from the middle of the beam:
   a) the beam balance no longer reliably reaches equilibrium although both objects weigh the same.
   b) The objects must be placed at the same distance from the middle of the beam. The further out an object is placed, the greater the effect on the leverage acting on the balance.
2. If one of the pans on the balance cannot move freely, this has a similar effect as in experimental task 1: The pans are no longer at the same distance from the middle of the scale when the scale is deflected. So the result can be falsified.

Attachments

Beam balance

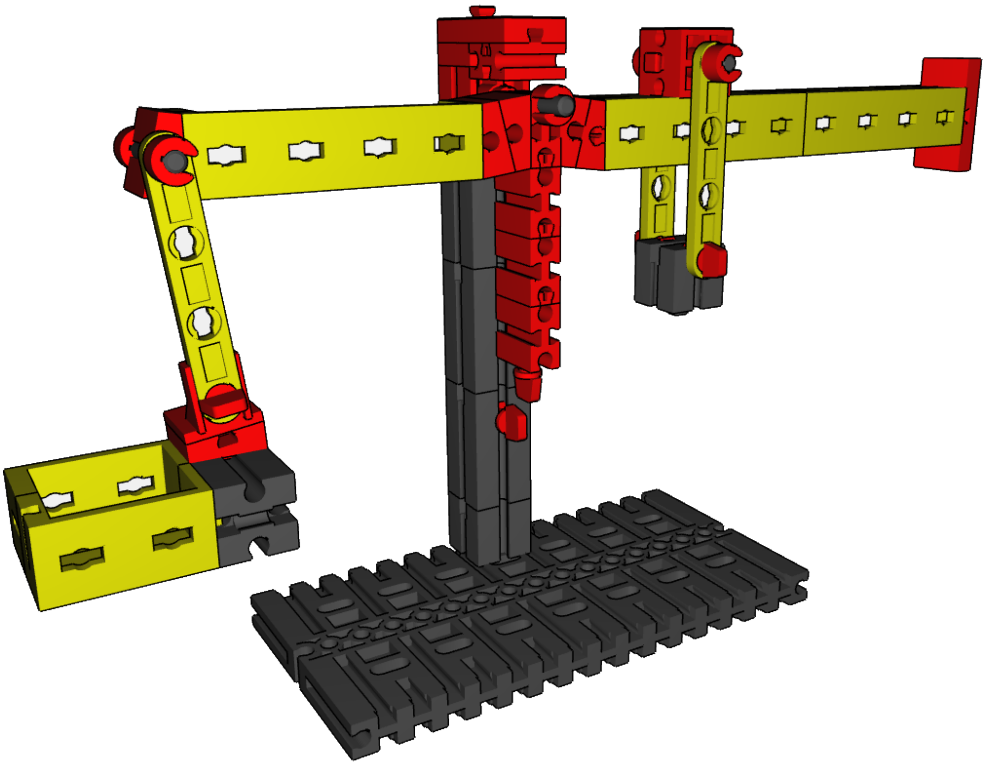
Further information

[1] Wikipedia: Beam balance.

Name: __________ Class: ___ Date: ________

Solution sheet model 5

Sliding balance



Topic tasks

1. If you move the balance weight **closer** to the fulcrum, the pan is lowered. If the balance weight is moved further away from the fulcrum, the pan **rises**.

2. [x] the weight must be moved away from the fulcrum

3. [x] the weight has to be moved even further out

The **larger** the weight placed in the pan, the further the balance weight has to be moved **out**.

The limits of the weights to be weighted are set by the size of the counterweight and the possible sliding range.

Experimental tasks

1. Measurement/adjustment for task 2
2. This way, we have measured which other parts weight exactly the same as a building brick 30.

   So if the position of the balance weight is not changed, we can measure whether weights of different objects...

   [x] are the same

   [x] are heavier

   [x] are lighter

In task 1, we used building block 30 to **set** or **adjust** the weight to be measured by the sliding balance.

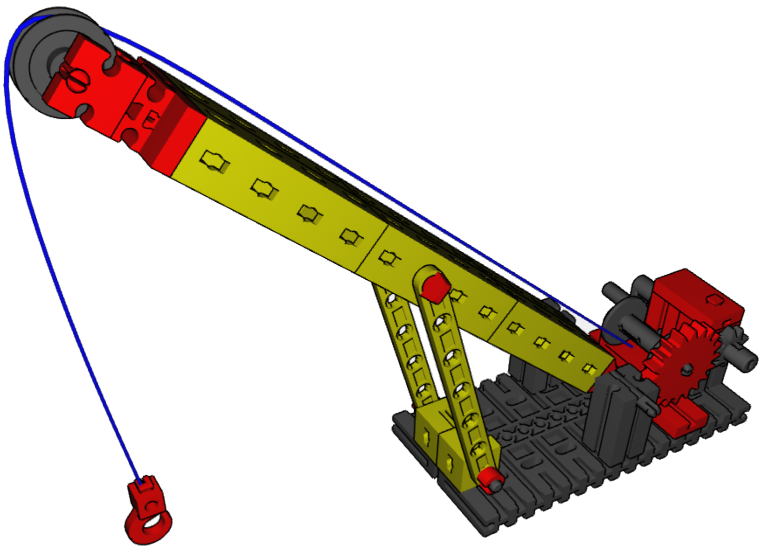
Name: ___________ Class: ___ Date: _________

Solution sheet model 6

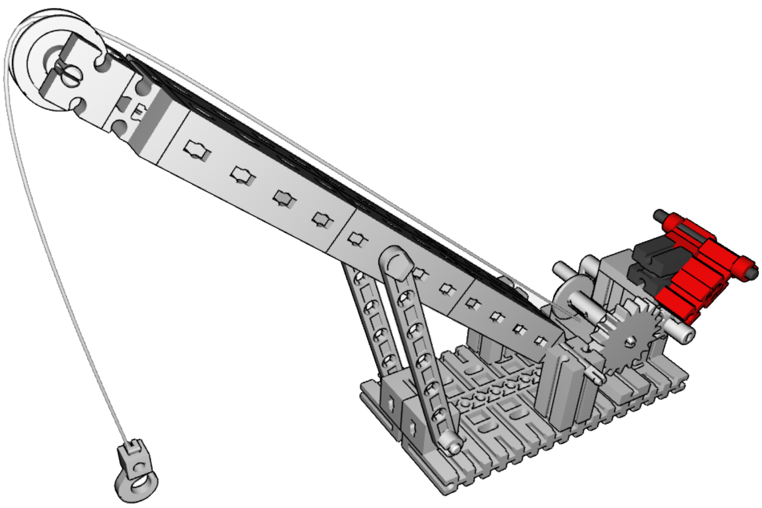
Crane

Construction tasks

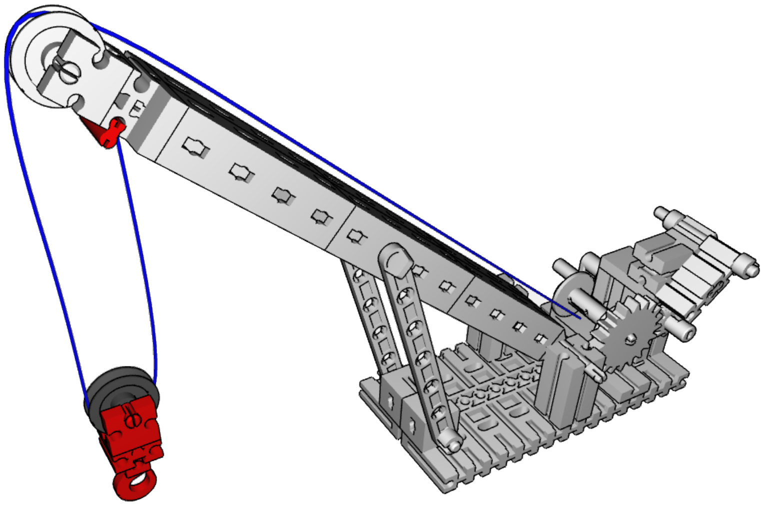
1. Without tower and pawl:



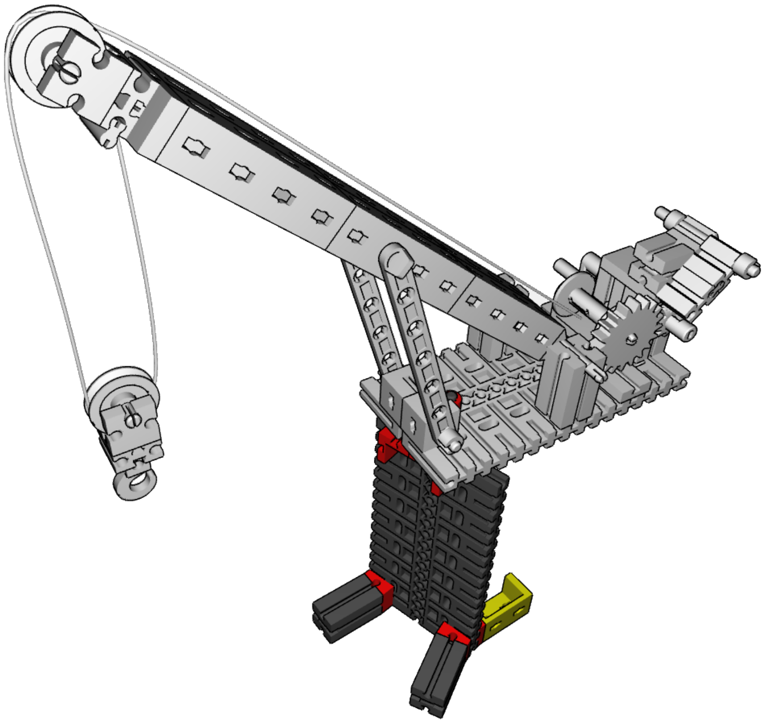
2. With pawl:



3. With pulley:



4. With tower:



Topic tasks

1. Without pawl, pulley and tower:

    a) The crane hook can be pulled down easily. It could hardly bear any weight because nothing is holding the rope tight.

    b) If you look carefully, you can see that the Z10 is turning faster than the Z20. Every time the Z20 revolves once, the Z10 (and the crank) revolve twice. This means the crane rope is wound up more slowly than without the gear drive - but you don't need as much force, and can still pull the rope with more force.

    c) The flatter the crane arm angle, the further away the material to be lifted can be from the crane.

       The steeper the crane arm, the closer the material to be lifted has to be to the crane. However, it can be lifted higher because the crane arm is now raised further.

2. The pawl solves the problem from task 1. a). If it is resting on Z10, the rope can no longer unwind itself (providing you have made sure the rope comes from the rope drum "from the bottom"). It is only now possible for the crane to hold a weight without the crank having to be held tight.

   To lower the crane rope, you just have to lift the pawl a little so that the teeth of the gear wheel Z10 can rotate freely under it.

3. Like the gear drive, the pulley ensures that the crane hook is raised even more slowly when you turn the crank. But in return, the weight suspended from the hook is now distributed to two rope strands. Each of these only has to bear half the weight.

   Since we are only pulling one of the rope strands with the crank and rope drum, we only need half the force for this as well. This means we can lift larger weights using less effort! The only thing is, lifting is now slower.

4. With tower:

   a) If the weight on the crane hook is too heavy, the tower will topple over. In the case of a real crane, this would be a dangerous accident! (This is true without the tower as well - give it a try!)

   b) If the crane is at a flatter angle, but projects out further, the crane will tilt with even smaller weights than it if its at a steeper angle and ends close to the base.

Experimental tasks

1. Longer bases provide further protection against the crane toppling over if weights are too heavy. In other words, larger weights can be attached. However, you have to be careful when slewing the crane if the bases are not the same length in all directions.

2. If the bases are lengthened to the “rear”, it makes no difference to the lifting of heavy weights at the front but helps prevent tilting if the crane is slewed to the rear.

Attachments

Crane

Supplementary material

- A household rubber band or other string can be useful to attach objects to the crane hook.
- Any kind of objects – fischertechnik parts, pens, whatever - can be lifted using the crane.

Further information

[1] Wikipedia: *Crane*. (This article presents other types of crane as well.)

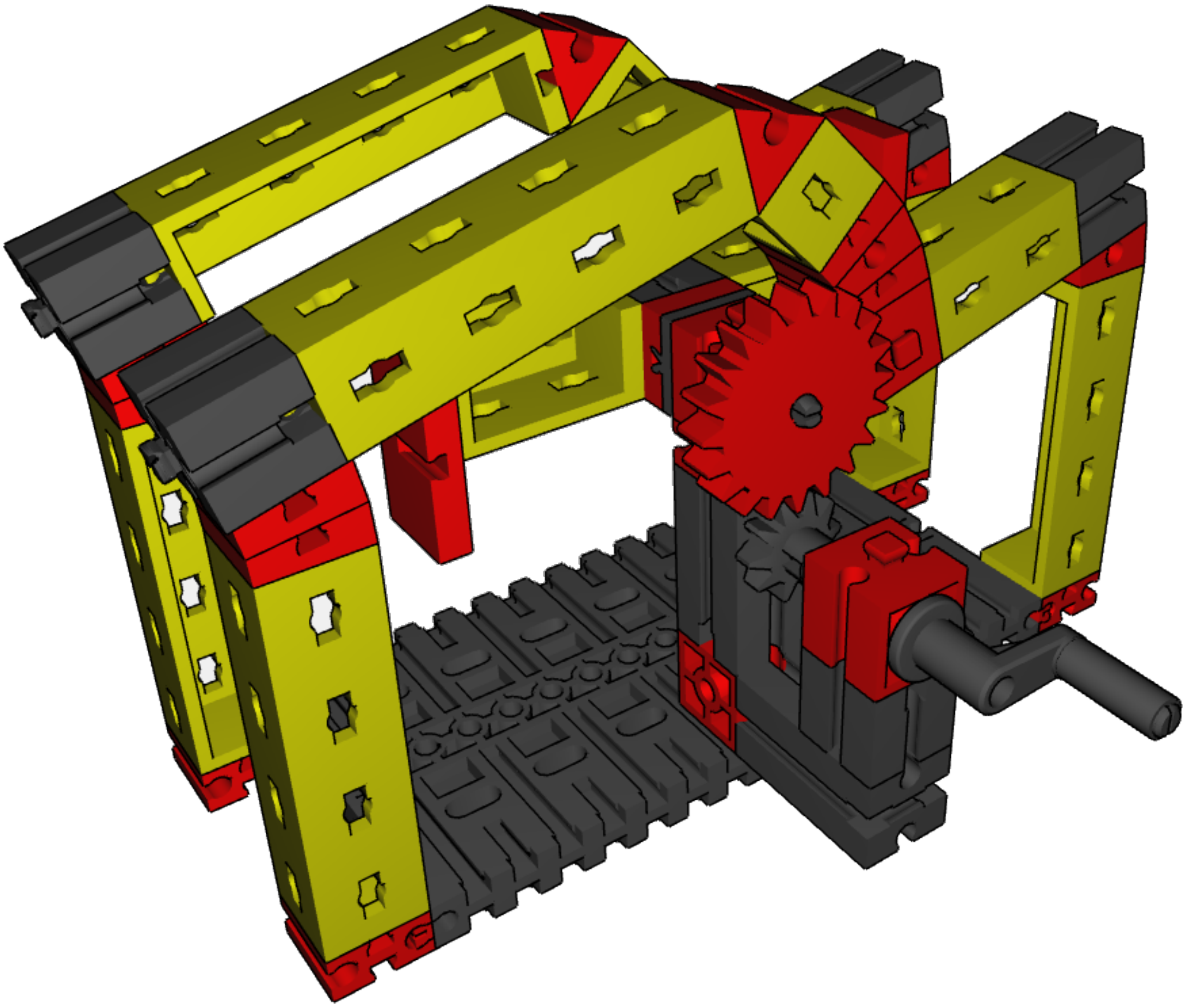
[2] Wikipedia: *Ratchet*.

Name: ___________ Class: ___ Date: _________

Solution sheet model 7

Ball passing 1 - Rotary lever

Construction task



Topic tasks

1. The levers pick up the ball from below and lift it. The red flat building blocks on the end prevent the ball rolling off the lever. The ball is guided by the track the whole time, which stops it rolling out to the left or right. Once it gets to the top, the ball rolls down the track exit. If you crank "the wrong way round", the balls are not lifted - the model only works in one direction.

2. The models suggested can and should be adapted or supplemented by new structures. One prerequisite is that attention is paid to the so-called interfaces of new modules, so that they can be connected together.

Experimental tasks

1. You have to turn the crank twice for the levers to rotate once. This is due to the "step-down ratio" of the black gear wheel Z10 to the red gear wheel Z20 (which we learned about on the "Crane" sheet). When Z10 has been turned once by the crank, wheel Z20 has only been turned by 10 teeth. This is why you need two revolutions of Z10 for Z20 to make one full revolution.

2. Our model has two lever arms. This means that two balls can be lifted per revolution. Although the levers only revolve at half the speed the crank is turned at, this results in one ball lifted per revolution of the crank.

Attachments

Ball passing - Rotary lever

Supplementary material

- Table tennis balls

Further information

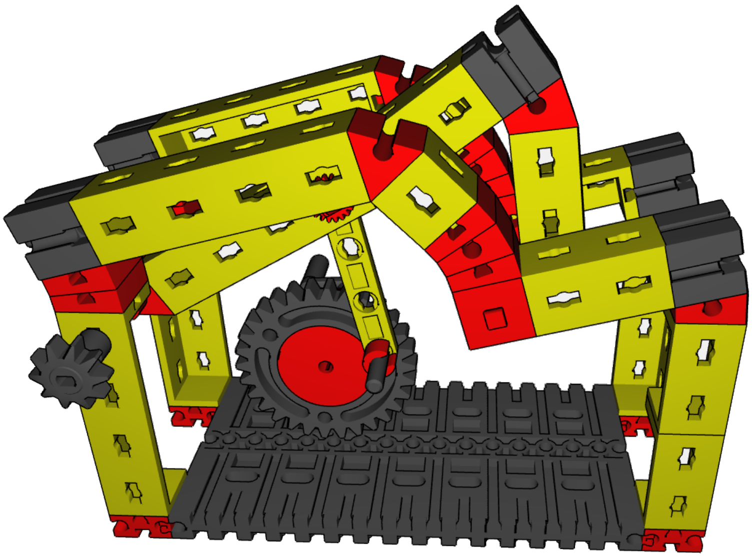
[1] Wikipedia: *Gear*

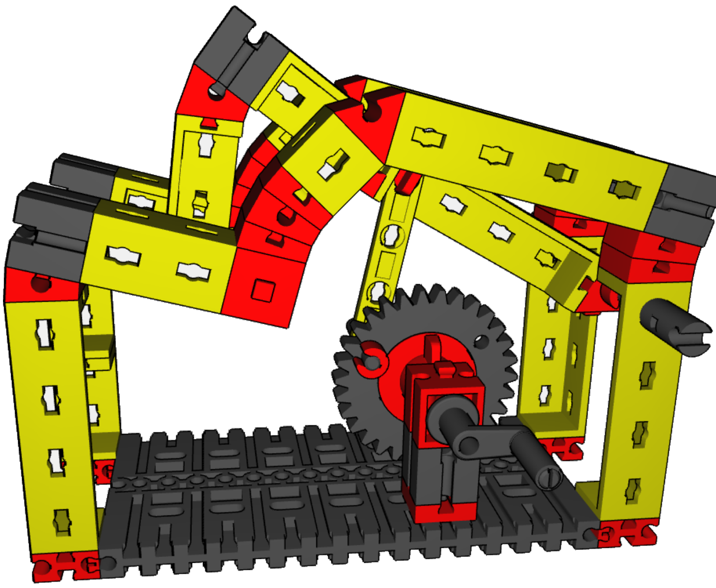
Name: ___________ Class: ___ Date: _________

Solution sheet model 8

Ball passing 2 – Four-bar linkage

Construction task





Topic tasks

1. a) Eccentric gear

   The axle with the I-strut 45 inserted in the gear wheel turns

   [x] outside the centre of the gear wheel
   [ ] inside the centre of the gear wheel

   b) Four-bar linkage

   Find the **four rotating joints**, which are all connected to one another by lever: The centre of rotation of the gear wheel with the crank, the axle in the gear wheel with the rotating mounted strut (the "lever" here is the gear wheel itself), the rotating mount of the top of the strut in the long lever as well as the rotating support of the large lever at the model exit. Study the mechanisms and how they work in detail.

2. The models suggested can and should be adapted or supplemented by new structures. One prerequisite is that attention is paid to the so-called interfaces of new modules, so that they can be connected together.

Experimental tasks

1. One revolution of the crank raises and lowers the large lever once. For this reason, one revolution can lift and transport one ball.

2. The structural girder hanging downwards is important if several balls are inserted once after the other. It prevents a ball slipping under the lever when the lever is in the top position. Without it, the ball would roll under the lever and block it.

Attachments

Ball passing - Four-bar linkage

Supplementary material

- Table tennis balls

Further information

[1] Wikipedia: *Eccentric*.

[2] Wikipedia: *Four-bar linkage*.

[3] Wikipedia: *Mechanical linkage*.

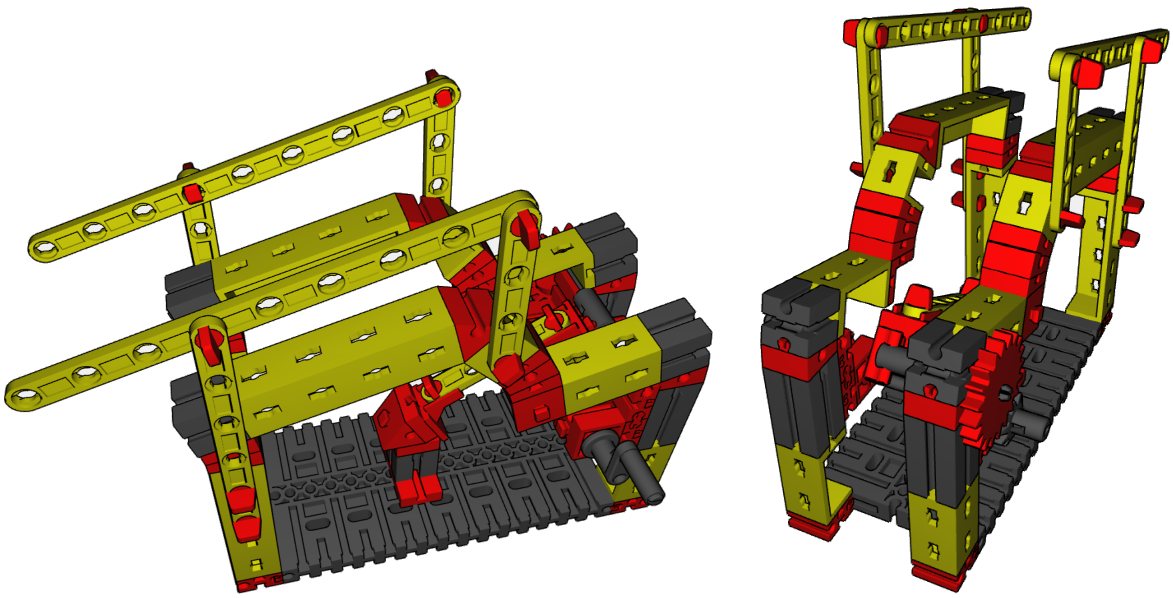
[4] Prof. Dr.-Ing. habil. Jürgen Dankert: *Planar quadrilateral linkage*.

Name: ___________ Class: ___ Date: ________

Solution sheet model 9

Ball passing 3 – Launcher

Construction task



Topic tasks

1. The structural strut 45 acts as a spring here. It is "wound up" by the rotating link 15 and suddenly released. This makes the S-rivet at the end of the strut strike the table tennis ball from below and make it shoot upwards. If everything has been adjusted properly, the ball is launched over the hill without leaving the track.

2. The models suggested can and should be adapted or supplemented by new structures. One prerequisite is that attention is paid to the so-called interfaces of new modules, so that they can be connected together.

Experimental tasks

1. You have to turn the crank twice for the levers to rotate once. This is due to the "step-down ratio" of the black gear wheel Z10 to the red gear wheel Z20 (which we learned about on the "Crane" sheet and in ball passing 1 - "Rotary lever"). When Z10 has been turned once by the crank, wheel Z20 has only been turned by 10 teeth. Since it has 20 teeth, two revolutions of Z10 are need for one complete revolution of Z20.

2. As in ball passing 1 - "Rotary lever", we have two lever arms, namely both ends of the link 15. One revolution of the lever can thus lift one ball with each lever arm - in other words two per complete revolution. So although the levers only revolve at half the speed the crank is turned at, this results in one ball lifted per revolution of the crank.

Attachments

Ball passing - Launcher

Supplementary material

- Table tennis balls

Further information

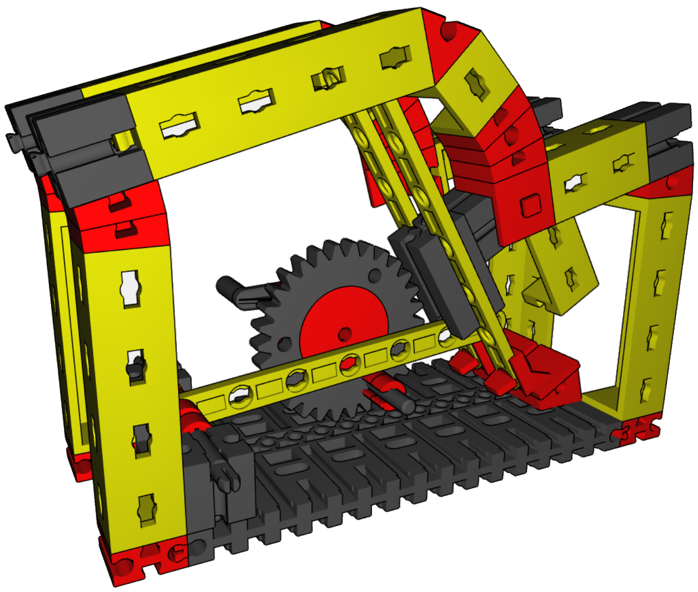
[1] Wikipedia: *Leaf spring* (in: *Spring*).

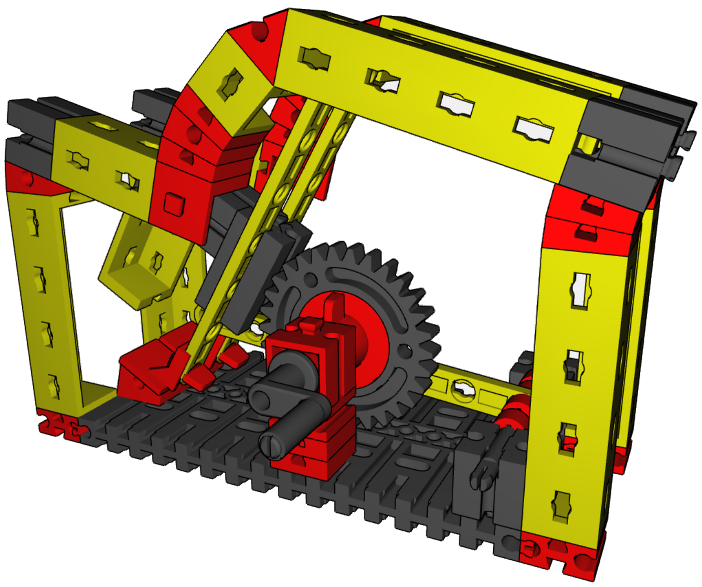
Name: __________ Class: ___ Date: ________

Solution sheet model 10

Ball passing 4 – Linear feed

Construction task





Topic tasks

1. The structural strut 45 acts as a spring here. It is "wound up" by the rotating link 15 and suddenly released. This makes the S-rivet at the end of the strut strike the table tennis ball from below and make it shoot upwards. If everything has been adjusted properly, the ball is launched over the hill without leaving the track.

2. The models suggested can and should be adapted or supplemented by new structures. One prerequisite is that attention is paid to the so-called interfaces of new modules, so that they can be connected together.

Experimental tasks

1. One revolution of the crank leaks to one upward and downward movement of the lift. This is why a table tennis ball can be lifted with one turn of the crank.

2. If the crank is turned evenly, the upward and downward movement **is not at the same speed**.

   The movement is always slower when the second axle inserted in gear wheel Z30 is at the front (towards the entrance of the model). It is faster when the Z30 axle is at the rear (towards the exit of the model). The axle in the Z30 is then closer to the axis of rotation of the strut, which is acting as a lever. The lever thus translates the movement of the axle in the Z30 into a faster movement at the end of the lever (when the lift is to be raised).

   Depending which direction the crank is turned in, this can be the upward or downward movement.

So the following applies for this model:

a) If the crank is turned clockwise (to the right), the upward movement is slower and the downward movement is faster.

b) If the crank is turned anti-clockwise, it moves up faster (and a bit harder) and down slower.

Attachments

Ball passing - Linear feed

Supplementary material

- Table tennis balls

Further information

[1] Wikipedia: *Slideway*.