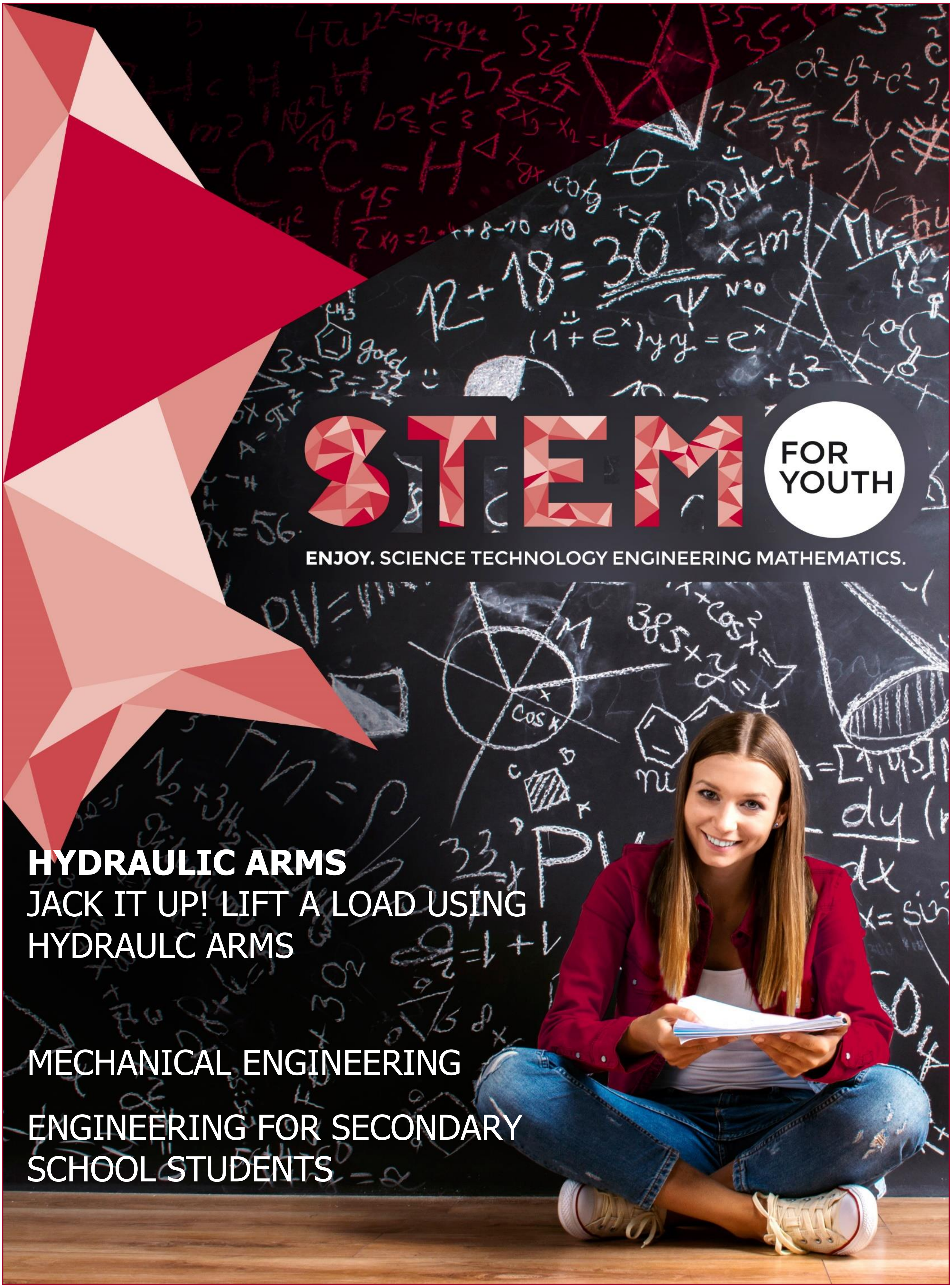

ENJOY. SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS.

HYDRAULIC ARMS

JACK IT UP! LIFT A LOAD USING HYDRAULC ARMS

MECHANICAL ENGINEERING

ENGINEERING FOR SECONDARY SCHOOL STUDENTS

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PROJECT DETAILS

PROJECT ACRONYM	STEM4YOU(th)
PROJECT TITLE	Promotion of STEM education by key scientific challenges and their impact on our life and career perspectives
GRANT AGREEMENT	710577
START DATE	1 May 2016
THEME	SWAFS / H2020

DELIVERABLE DETAILS

WORK PACKAGE NO. AND TITLE	WP5 – CONTENT CREATION, TOOLS AND LEARNING METHODOLOGY DEVELOPMENT
DELIVERABLE NO. and TITLE	**D5.1 MULTIDISCIPLINARY COURSE-ENGINEERING SUB-COURSE**
NATURE OF DELIVERABLE AS PER DOW	R=Report
DISSEMINATION LEVEL AS PER DOW	PU=Public
VERSION	**FINAL**
DATE	**JULY 2018**
AUTHORS	**EUGENIDES FOUNDATION**

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INDEX

INTRODUCTION

This challenge introduces the field of mechanical engineering. Students explore the scientific concepts of hydrostatic pressure, torque, Pascal's law. By constructing a model of a hydraulic arm, students realize how engineers use their knowledge of the previously mentioned scientific concepts and laws in order to design and build machines used in large scale constructions.

Hydraulics has a wide range of applications. The challenge can be implemented from schools to science museum and science fair workshops. The primary aim of this activity is to motivate students and young people to become interested in science and engineering.

In general, hydraulic arms can trigger and develop young people's curiosity while making the process of learning about science much more attractive.

Overview of the challenge:

Participant age: 13-18	Number of participants: Groups (3-4 students)	Module length: App. 1,5 hours to 4 hours
Level of knowledge: intermediate, advanced	No. and type of personnel: teacher / external science experts/science museum staff/students	Type of venue: Classroom / outdoors/science museum
Technological needs: internet / computer/ tablet /	Topic as per formal curricula: Pressure, Pascal's law, fluids, hydraulics, incompressibility, motion transmission	Estimated cost: low / intermediate / high (specify) Low (200 € per 5 teams) All the materials are reusable.
Specify learning methodology (D3.1): Engineering Design Process (EDP) Inquiry Based Learning (IBSE)	Engineering Field: mechanical	Type of activity: Hands on activity

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General Objectives: In this challenge students will

- understand the principal role of the materials and their properties in engineering solutions
- get interested in phenomena found in daily life
- develop the ability to predict and verify results
- realize the use of fluids in transmitting motion
- apply Pascal's law in real life problems
- realize the difference between natural and man-made objects
- conceive that goals are achieved by collaboration among scientists and engineers
- experience the importance of teamwork as well as individual responsibility as a member of the team
- experience the satisfaction of success
- discover and experience the relationship between theory and practice
- develop a spirit of inquiry
- develop the ability to accomplish a task from start to finish
- develop design skills
- develop the ability to turn designs into reality
- acquire technical skills on using tools properly and safely
- get familiar with the process of finding means to overcome difficulties and problems
- develop the ability to perform experiments and interpret results

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Activity 0-What is engineering?

Duration: 40 minutes (max)

Objectives: In this activity students will

- discover the differences between engineering and technology
- associate things, activities or other terms with engineering and technology
- familiarize with different engineering fields
- apply the Engineering Design Process in order to design and construct a paper table

General Context

This first activity is intended to encourage thinking about what engineering and technology are and to challenge the misconceptions that students may have about the field of engineering or the work of an engineer. This activity aims to disentangle the concepts of engineering and technology and develop the understanding that manmade objects are designed for a purpose and that technology, in a very broad sense, refers to any object, system or process that has been designed, constructed, modified in order to solve a problem or to meet a certain need. Finally, in this first activity, students are introduced to the process that engineers follow in order to find solutions to the problems they are dealing with. Student teams try to find and construct a solution to a simple problem following the same process as engineers do.

❖ **Small groups**

Teacher arranges students into of 3-4 person groups, preferable mixed gender and aptitude (teams should be kept the same through the entire challenge). Each group is asked to discuss and interpret the concepts of engineering and technology and try to associate things, activities or other terms with these concepts. Students are asked to answer to the following questions and write their answers down:

i. What is engineering?
ii. What is the work of an engineer?
iii. Can you give some every day examples of engineering and technology?
iv. What is the difference between engineering and technology?

After that, the teacher writes student team's answers on the board and initiates a discussion about engineering and technology. He/she seizes the opportunity to introduce the Engineering Design Process (EDP) steps and initiate a quick discussion about each individual step. Finally, the teacher asks student teams to construct a laptop table out of paper, by applying the EDP.

What is engineering?

The word engineering is of Latin origin; its root is "ingeniere" which means to design or to devise.

Engineering is the application of scientific knowledge (natural sciences, mathematics, economic and social), practical knowledge and empirical evidence in order to solve everyday life problems. More specific, the purpose of engineering is to invent, innovate, design, build, research and improve structures, machines, tools, systems, components, materials, processes and organizations under specific constraints. The field of engineering is very broad and encompasses a great range of more specialized fields [1], [2] such as:

- Aerospace & Aeronautical Engineering
- Agricultural Engineering
- Architectural Engineering
- Biochemical Engineering
- Biological Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Electrical Engineering
- Environmental Engineering
- Geoscience Engineering
- Industrial Engineering
- Materials Engineering
- Mechanical Engineering
- Metallurgical Engineering
- Ocean Engineering
- Petroleum Engineering

What is the work of an engineer?

Engineers identify a problem, and come up with a solution – often creating something completely new in the process.

"Scientists investigate that which already is; engineers create that which has never been." (Albert Einstein)

The most famous engineering fields, in more detail [1], [2], are the following:

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Aerospace engineering: the field of engineering concerned with the development of aircraft and spacecraft. Aerospace engineers design, develop, test, and supervise the construction of aerospace vehicle systems. Such systems are aircrafts, helicopters, space vehicles and launching systems.

Architectural engineering: the field of engineering that uses engineering principles to the construction, planning and designing of buildings and other structures. Architectural engineers work in several areas such as: the structural integrity of buildings, the design and analysis of light, heating and ventilation of buildings, energy conservation issues.

Biological engineering (bio-engineering): the field that applies concepts and methods of biology, physics, chemistry, mathematics and computer science to solve problems which are related to life sciences. Bioengineers solve problems in biology and medicine by applying principles of physical sciences and engineering while applying biological principles to create devices such as diagnostic equipment, biocompatible materials, medical devices etc. In general, bioengineers try to mimic biological systems in order to create products or modify and control biological systems.

Chemical engineering: the field of engineering that applies physics, chemistry, microbiology and biochemistry along with applied mathematics and economy in order to transform, transport and use chemicals, materials and energy. Traditionally chemical engineering was linked to fuel combustion and energy systems, but today's chemical engineers work in medicine, biotechnology, microelectronics, advanced materials, energy and nanotechnology.

Civil engineering: the engineering field that deals with design, construction and maintenance of constructions such as roads, bridges, dams, buildings, tunnels. Civil engineering is probably the oldest engineering discipline which deals with the built environment. Civil engineers use their knowledge on physics and mathematics to solve society problems.

Computer engineering: the discipline that integrates electrical and electronic engineering and computer science in order to design and develop hardware, software, computer systems and other technological devices. Computer engineers embed computers in other machines and systems, build networks to transfer data and develop ways to make computers faster and smaller. Furthermore, computer engineers have expertise in a variety of areas such as software design and coding and are trained to design software and perform and integrate that software with hardware components.

Electrical engineering: the field of engineering that deals with the study and application of electricity, electronics and electromagnetism. Electrical engineers conceive, design and develop circuits, devices, algorithms, systems and components that can be used to sense, analyze and communicate data. Electrical

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engineers work on a variety of projects, such as computers, robots, cell phones, radars, navigation systems and all other kinds of electrical systems.

Materials engineering: the field that involves the discovery and design of new materials. Material engineering incorporates physics, chemistry, mathematics and engineering. Materials engineers develop, process and test materials used to create a wide range of products such as computer chips, medical devices, aircraft components etc. Materials engineers are concerned with the structure and properties of materials used in modern technology so they study the properties and structures of metals, ceramics, plastics, nanomaterials and other substances in order to create new materials that meet certain mechanical, electrical or chemical needs.

Mechanical engineering: the engineering discipline which applies the principles of engineering, physics and mathematics for designing analyzing manufacturing and maintaining mechanical systems. Mechanical engineers create machines used in manufacturing, mechanical components of electronics, engines and power-generating equipment, vehicles and their components, artificial components for the human body, and many other products.

Ocean (Marine) engineering: the branch of engineering study that deals with the design and operations of manmade systems in the ocean and other marine environments. Ocean engineering includes the engineering of boats, ships, oil rigs and any other marine vessel or structure. Ocean engineers apply their engineering (mechanical, electrical, electronic engineering) and scientific knowledge in order to design and develop systems and structures in marine environments. An ideal ocean engineer has to achieve a proper tandem between the marine eco-system and the developed human world.

Robotics: the interdisciplinary branch of engineering and science that deals with designing, constructing, programming, controlling, operating and using robots. Robots are used in a wide range of applications which include industrial, military, agricultural, medicine robots etc.

- <u>Industrial robots</u> - take over work that is dirty, dangerous and degrading to the human spirit (e.g. arc welding, grinding, sanding, polishing and buffing, palletizing etc). Typically, these robots are articulated arms particularly created for applications like- material handling, painting, welding and others.
- <u>Medical robots</u> – robots that are employed in medicine and medicinal institutes such as surgical robots, rehabilitation robots and biorobots.
- <u>Domestic or household robots</u> – These types of robots are used at home and consist of robotic pool cleaners, robotic sweepers or robotic vacuum cleaners.

- Military robots – These types of robots are used for offensive or defensive purposes and include bomb discarding robots, ballistic shield robots, inspection robots, attacking drones etc.
- Space robots - Robotic devices used to aid, augment, or substitute astronauts in order to do difficult or rote tasks such as exploration or repairs in dangerous environments (e.g. space station robotic arms, Mars rovers Spirit and Opportunity).
- Deep Sea robots – Robots that have long-term presence in the deep ocean and carry equipment to measure various parameters that scientists are interested in (e.g. Benthic Rover).

➢ Engineering Misconceptions
- Plumber
- Electrician
- Carpenter
- Auto Mechanic
- PC (Personal Computer) Technician
- Welder
- Machinist

What is technology?

Engineering and technology are intertwined terms in society. In order to disentangle the two terms, one needs to understand what their meaning is. Engineering is both a field of study as well as application of scientific knowledge to create or produce something. On the other hand, technology is the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation. Technology can be the knowledge of techniques and processes, or it can be embedded in machines, computers, devices, and factories, which can be operated by individuals without detailed knowledge of the workings of such things.

Engineering Design Process

The teacher introduces the EDP steps to the students. A short description of the Engineering Design Process follows.

The Engineering Design Process (EDP) is a series of steps that engineers follow when they are trying to solve a problem they are facing and consists of a methodical approach. However, there is no single design process which is universally accepted. In general, each individual design process begins with identifying the problem and its requirements and ends up with a proposed

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solution. The intermediate steps, however, can vary. It is very important to point out that EDP is not a linear process. Since, engineering problems can have numerous correct answers; the process may require backtracking and iteration. The solution to an engineering problem is usually subject to unexpected complications and changes as it develops. In this project we propose a series of steps which are described below.

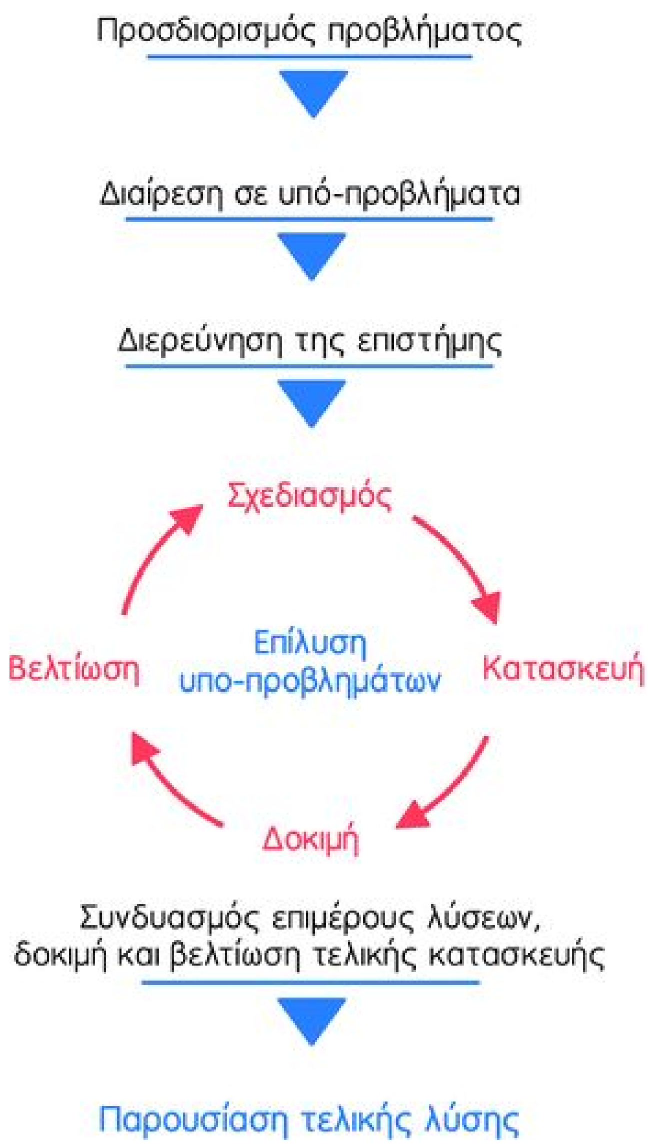

Figure 1: EDP steps

1. <u>Identify the problem</u>

Engineers ask critical questions about the problem and what they want to create, whether this is a space station, a skyscraper, a car or a computer. These questions include:

- *What is the problem?*
- *Define the problem in specific terms. Be as specific as possible.*
- *Which are the available materials?*
- *What do we need to know in terms of scientific principles that underlie the problem?*
- *What are the constraints of the problem? (Budget, time etc.)*
- *Which are the criteria that must be met so that the solution is acceptable?*

2. <u>Divide problem into sub-problems</u>

Usually big problems consist of a series of sub-problems. So, engineers analyze the problem in order to plan their work.

- *Is the solution to the main problem straight forward?*
- *Does the main problem consist of smaller and simpler problems?*
- *Engineers do not attempt to plan the whole thing at once. Large projects have many variables that you do not know and can affect the whole plan.*
- *Engineers set smaller goals. Instead of trying to plan everything from the beginning, they figure out the first obvious step and then move to the next one.*

3. <u>Explore the science</u>

After dividing the main problem to the sub-problems it consists of, engineers investigate the scientific principles that underlie each sub-problem. The fundamental background science is essential for solving sub-problems and designing the optimum solution.

- *What areas of science cover my project?*
- *Which are the scientific principles that underlie each sub-problem?*
- *Research background theory*
- *Perform experiments-tests to understand the theory's applications.*

4. <u>Solve sub-problems</u>

Generate as many solutions as possible by brainstorming and examine the advantages and the disadvantages of each possible solution. Evaluate all the solutions in order to identify the optimum.

- *Design: Design the application of the chosen solution, carefully and with as much detail as possible. Draw a diagram of the solution and make a list of materials you need.*
- *Build: Follow your design and develop your solution of each one of the sub-problems*
- *Test: Test whether the solutions of individual sub-problems are compatible with each other*
- *Improve: Make the necessary corrections and improvements*

5. <u>Combine sub-solutions, test and improve</u>

Combine the different components that will provide you the final, integrated solution to the main problem.

Test and if necessary improve your final design

- *Does it work?*
- *Does it solve the need?*
- *Does the final design meet the criteria set?*
- *Analyze and talk about what works, what doesn't and what could be improved.*
- *Discuss how you can improve your solution*

6. <u>Present final solution</u>

Review and evaluate your work and present your final solution in front of an audience.

Preparatory activity - Strong Paper Table

This activity is designed as a way to introduce students to the EDP in order to have a common understanding of how it works and help teachers who are not familiar with engineering and technology in their classrooms.

Can you build a newspaper table that won't collapse under the weight of a laptop?

Student teams are asked to follow the design process to build a sturdy and steady laptop table out of paper. Find a way to make paper support weight and prevent the legs of the table from buckling (see Fig. 2 for possible solutions).

<u>Criteria</u>

- The table must withstand a weight of 2-3 kg.
- The table must be sturdy and stable.
- The table's surface must be inclined to make the use of keyboard easier.
- The table's surface must be ventilated, to prevent laptop from overheating.

<u>Constraints</u>

- The available materials are 5 newspapers and 50 A4 sheets of paper.
- The available tools are duct tape and a pair of scissors.
- The available time is 30 minutes

-Tip: *From the criteria the main problem can be divided into sub-problems*

- *Stability and durability of the table*
- *Inclination*
- *Ventilation*

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Figure 2: Possible Solutions

Activity 1-Identifying the problem (what is the engineering problem?)

Duration: 20 minutes

Objectives: In this activity students will

- familiarize with materials and tools such as pliers, screw drivers, screws, wrenches etc.
- reflect the role of materials in designing a solution to their problem

General Context

In this activity the teacher sets the engineering problem that students have to face. Student teams ask questions concerning the problem they are facing and discuss with their teacher the criteria that their solution must meet as well as the constraints they have. Afterwards, each team prepares a problem statement i.e. a brief description of the issues that need to be addressed by a problem solving team and should be presented to them (or created by them) before they try to solve a problem.

Finally, student teams discuss with their teacher about materials that could be appropriate for their challenge. Different types of materials and tools are provided to student teams and the teams explore and become familiar with the materials.

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❖ **Working in groups**

The teacher briefly introduces the Engineering Challenge: "Each team has to construct a hydraulic arm able to lift a weight of 500 g and unload it into a specific higher position".

The teacher states that engineers who face and deal with problems such as the one under study are called *Mechanical Engineers*. (Description of this field is provided in Activity 0).

The teams are encouraged to ask questions concerning the problem:

- What is the problem or need?
- Which are the criteria that their solution must meet?
- What are the constraints of the problem?
- Which are the available materials, tools, resources and technologies?
- Which are the scientific principles behind the problem?
- Which every-day materials that can be found at home or at a local hardware shop that can be useful for solving the problem?

Each team is asked to prepare a problem statement. A good problem statement should answer these questions:

1. What is the problem? This should explain why the team is needed.
2. Who has the problem or who is the client/customer? This should explain who needs the solution and who will decide the problem has been solved.
3. What form can the resolution be? What is the scope and limitations (in time, money, resources, technologies) that can be used to solve the problem?

The problem must be specific enough to allow each team to design a solution.

The teacher then provides student teams with different materials (the teacher can provide student teams with extra materials that are not appropriate for the final design) and tools. Student teams are given some time to become familiar with the materials and tools and then discuss with their teacher possible uses of them. The teacher should encourage student teams to ask questions concerning the criteria that their solution must meet and the constraints of the problem.

<u>Constraints</u>

- Available materials
- Available tools
- Available time
- The arm's size
- Cost
- Security Issues

<u>Criteria</u>

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- The arm must be able to grip things
- The arm must be able to lift weights up 500 g
- The arm must be able to transmit motion in different axes
- The arms must have 3-4 degrees of freedom

Activity 2 – Divide into sub-problems

Duration: 15 minutes

Objectives: In this activity students will

- brake the main problem to simpler problems
- organize their goals
- schedule their work and set time limits
- draft a plan how they will work

General Context

In this activity, student teams move to the second step of the Engineering Design Process which is to divide the main problem into sub-problems. Student teams try to analyze and divide the bigger problem to smaller and easier to handle sub-problems. They also try to match materials to each sub-problem. Student teams write down and justify their thoughts. The teacher reminds the criteria and constraints that should be met.

❖ **Working in groups**

Teacher initiates a discussion about the fact that an easy way to deal with a large project is to break it into smaller tasks which are more manageable and easier to face. However, he/she should point out that the task of getting a large goal divided into smaller and achievable ones is not very easy and in fact it can be something quite hard to do. The teacher can propose some simple guidelines that if followed can make the process of breaking the problem, easier. After that student teams should be prompted to propose possible sub-problems.

Guidelines

- Do not attempt to plan the whole thing at once. Large projects have many variables that you do not know and can affect the whole plan.
- Set smaller goals. Instead of trying to plan everything from the beginning, figure out the first obvious step and then move to the next one.
- Do not hesitate to re-divide. If you are procrastinating on any of the smaller task, do not hesitate to analyze to simpler ones.
- Set time limits. Usually, when engineers deal with a complex problem, apart from the problem itself they have to face time limitations. So in order to be effective manage your time as good as possible.

The main problem can be divided into four sub-problems:

1. The gripper

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2. The lifting arm
3. The rotation base
4. The control system

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Activity 3- Explore the science

Duration: 50 minutes

Objectives: In this activity students will

- perform experiments concerning the principles of hydraulics
- organize and classify their observations
- predict and verify results
- familiarize with the third step of the Engineering Design Process

General Context

The purpose of this activity is to get students in touch with the **process of exploring the science behind the problem and/or sub-problems.** Student teams start to think about the necessary knowledge they need in order to solve the engineering problem. Student teams are encouraged to pose investigative questions which if answered will help them in the process of dealing with the problem. They perform specific experiments that will guide them answer their questions about the science that underlies the problem. Student teams are guided through the process of acquiring the necessary scientific knowledge they need for solving the problem. As this activity progresses, students discuss with the teacher the science that underlies the problem. In addition, students organize their observations/answers.

❖ **Working in groups**

The teacher's goal is to introduce students to the third step (Explore the science) of the EDP and to motivate them start thinking about the scientific knowledge they need to know and to start brainstorming on how this knowledge can be applied by imagining possible solutions to the engineering problem. Teacher should focus on the scientific principles that underlie the challenge. Student teams are asked to brainstorm and pose questions concerning the science behind hydraulic arms.

The key questions which are important to investigate and are the focus of this activity are:

- What areas of science cover my project?
- Which are the scientific principles behind the problem?
- How is motion transmitted through a fluid?
- How is force transmitted?
- How is force multiplied?

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➢ The science behind hydraulic arms

Student teams are asked to perform (or discuss) the following experiments, which will guide them through the basic physical laws and principles they need to know in order to find a solution to the problem they are facing. ***Note:*** *The following experiments are recommended or optional. Teacher may skip some of them or perform others of his/her choice. The challenge takes into account the realities of a teacher's life such as limitations of time, and equipment/materials, the amount of flexibility they have within their curricula, and other particular constraints imposed by their curricula.*

1. Can you explain what is happening in the following pictures? Why isn't the balloon popping? Why the person isn't hurting his back? Why do Eskimo's wear rackets on their feet?

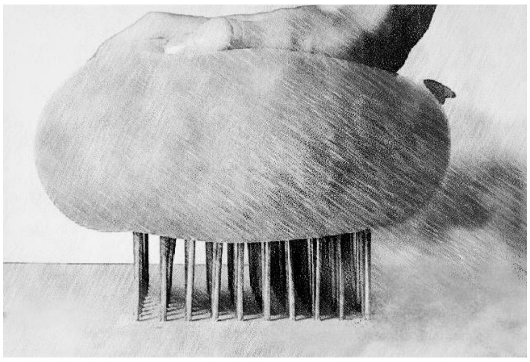

Figure 3

<u>Answer</u>

Pressure is the amount of force applied perpendicular to the surface of an object per unit area over which the force is distributed.

$$P = \frac{F}{A}\left(\frac{N}{m^2} = kg\ m^{-1}\ s^{-2} \equiv Pascal\right) \quad (1)$$

i. If you push the balloon against one nail the balloon will pop. However, when pushing the balloon against a bed of nail, applying the same force as previously, the balloon doesn't pop. The reason why this happens can be explained in terms of pressure. In Eq. (1) we can observe that the numerator (force) remains constant while the denominator (area) changes (becomes larger). Because, the denominator becomes larger, pressure becomes smaller. That is why the balloon doesn't pop. In fact, pushing against many points spreads the force and reduces pressure. When you pop the balloon with a nail, all the force is concentrated on one point (high pressure) on the balloon. When you place the balloon on the bed of nail, the pressure points are spread across the surface of the balloon (low pressure).

ii. Just like the balloon, when a person lies on a bed of nails, his/her body is evenly distributed across the surface of the nails. So the pressure is low and the person doesn't get hurt.

iii. For the same reason, Eskimo's place rackets on their feet, in order to increase the surface area of their feet and thus reduce pressure. Otherwise, their feet, which have smaller area than the rackets, will apply high pressure on the ground and thus will sink in the snow.

2. What exerts more pressure per square meter, when walking, a 60 kg woman in high heels (stiletto) or a 3,000 kg elephant? Who would you like to step on your foot? Think about it carefully!

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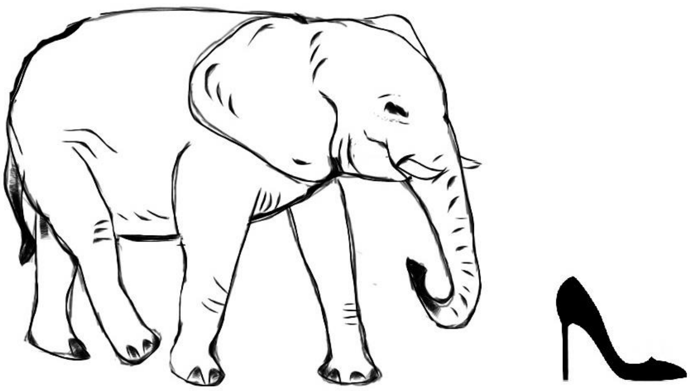

Figure 4

Answer

- Elephant: Let as assume that the elephant steps on your foot with his one leg. The elephant's foot has an area of $0.1m^2$ and the elephant's mass is 3,000 kg. The force exerted on your foot is:

$$F_{Elephant} = \frac{m_{El} * g}{4} = \frac{3{,}000 * 10}{4} = 7{,}500\ N$$

So the pressure on your foot is:

$$P_{Elephant} = \frac{F_{Elephant}}{A_{foot}} = \frac{7{,}500}{0.1} = 75{,}000\ N/m^2$$

- Woman: The woman steps on your foot with one heel. The heel has an area of 0,0001 m^2 and the woman's weight is 60 kg.
The force exerted on your foot is:

$$F_{Woman} = \frac{m_w * g}{2} = \frac{60 * 10}{2} = 300\ N$$

So the pressure on your foot is:

$$P_{Woman} = \frac{F_{Woman}}{A_{stiletto}} = \frac{300}{0.0001} = 3{,}000{,}000\ N/m^2$$

-*The purpose of these activities is to introduce the students to the concept of pressure.*

3. Try to explain why when you squeeze the toothpaste tube from the bottom you have the toothpaste come out easily from the mouth of the tube.
Answer

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According to Pascal's principle pressure applied to an enclosed liquid is transmitted equally to every part of the liquid. So, when you squeeze one end of the toothpaste tube, toothpaste emerges from the other end. The pressure has been transmitted through the fluid toothpaste).

4. Get a toothpaste tube and make 4-5 holes on the tube, on different places. Keep the cap of the tube closed and apply pressure at a particular point on the tube. What do you observe? Can you explain your observation?

   Answer
   A closed toothpaste tube can be considered as an example for a simple hydraulic system. The toothpaste can be considered as a hydraulic fluid working inside the system which is confined. Four or five holes are made on the tube. By keeping the cap of the toothpaste tube closed, apply pressure at a particular point on the tube. This makes the toothpaste to come out from all the holes evenly. This is a simple example to understand Pascal's law. Thus force applied at a particular point on a fluid in closed system, transfers equal force on all other parts of the system. Further, the force acts perpendicular to the walls of the confined area.
   http://www.brighthubengineering.com/hydraulics-civil-engineering/43171-what-are-the-basic-principles-of-hydraulics/).

5. *Make a hydraulic jack*

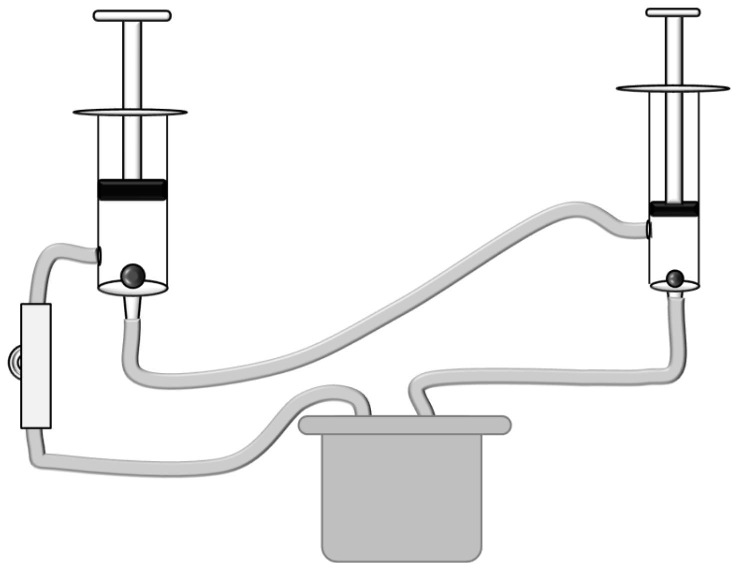

Figure 5
(https://www.youtube.com/watch?v=4xegpADGUBM
http://teacherweb.com/MA/SERSD/Kent/apt53.aspx)

-The purpose of these activities is to introduce the students to Pascal's law and transmission of force.

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6. The teacher provides each student team with two syringes. One is filled with water while the other is filled with air. Students are asked to clog the nozzle of the syringe with their hands and to try and push the plunger of each syringe in order to compress its content. What do you observe?

   <u>Observation</u>
   Students will observe that they can push, quite easily, the plunger of the syringe which contains air. However, when they move to the syringe that contains water they will observe that pushing the plunger is almost impossible. That is because air (gas) is compressible while water (liquid) is highly incompressible.

-The purpose of this activity is to demonstrate the fact that water is highly incompressible while air can be compressed.

➢ <u>Technical issues</u>

Student teams are asked to brainstorm (considering the previously discussed experiments) and discuss with the whole class their ideas about possible materials (which can be found at home or at a hardware store) that may be appropriate for constructing and operating a hydraulic arm. Furthermore, the teacher provides student teams with the tools they are going to use and gives a small description of the use of each tool.

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Activity 4 – Solve sub-problems

Duration: 50 minutes

Objectives: In this activity students will

- solve each sub-problem based on their plans
- use tools properly and safely

General Context

In this activity students are introduced to the core of the Engineering Design Process and apply the corresponding steps of EDP to face their challenge. After the completion of activities 1, 2 and 3 in which students have investigated the scientific principles and the technical issues and have broken the main problem into sub-problems, they move to the construction process. In order to face and solve each sub-problem they follow the circle: design-build-test-improve. As a part of the whole EDP process students need to recall the scientific knowledge they gained in Activity 3.

❖ **Working in groups**

The teacher summarizes the conclusions of Activities 1, 2 and 3. As student teams have already defined the individual sub-problems, the teacher encourages and guides student teams to gradually solve each one of the sub-problems that the main challenge has been divided into. Student teams are also asked to classify the available materials according to the sub-problem they believe that are suitable for. The teacher encourages the teams to draft a plan of their work and a simple design illustrating the different components of the final design, i.e. the grasping hand, the lifting arm, the base and the control system. Finally, student teams are asked to move on the construction part. **Note:** *This activity must be performed taking into consideration the construction instructions (see related part below).*

The teacher should take into account the following:

➢ Sub-problem 1: The gripper must be able to grasp an object of 8 cm in diameter.

➢ Sub-problem 2: The lifting arm must be able to lift weights up to 200 g.

➢ Sub-problem 3: The rotation base. The whole mechanism must be able to rotate about 45 degrees.

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- <u>Sub-problem 4: The whole mechanism must have a control system made of levers that enable the user to handle the arm properly and efficiently.</u>

The teacher should decide whether the members of each team will have certain tasks (for example half the team will deal with the grasping hand and the lifting arm while the other half with the rotation base and the control system) or the whole team will deal with every sub-problem.

Activity 5 – Combine sub-solutions, test and improve

Duration: 45 minutes

Objectives: In this activity students will

- combine solutions of individual sub-problems to end up with the final design
- explore the function of water in transmitting motion
- use their design to probe whether the criteria are met or not
- make all the necessary changes to improve their design
- have fun with their design

General Context

By the end of Activity 4, student teams are supposed to have found a solution for the grasping hand, the lifting arm, the rotation base and the control system. The next step is to combine the different components that will compose the final device. Student teams test their construction in order to confirm that it is functional and meets the criteria set in previous steps. Student teams, experiment with different weights and different heights and in general test the functionality of the design.

❖ **Working in groups**

The teacher initiates a discussion about the compatibility of the different components of the final design. Student teams are prompted to fit pieces together in order to construct the final artifact. As soon as the hydraulic arm is ready, student teams test their designs. Each team performs several tests (every member of a team should try the hydraulic arm). The teacher encourages student teams to carefully observe the behavior of the hydraulic arm and try to find any flaws or mistakes in their design that if fixed the arm will be substantially improved.

-Tip: *From an educational standpoint, it's important to allow the children to participate in setting up/cleaning up the room.*

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Activity 6 – Present Final Solution

Duration: 20 minutes

Objectives: In this activity students will

- Organize their presentation as a team
- present their team work in front of an audience

General Context

The purpose of this activity is to help students realize that they used the same process that engineers use in solving problems. Students also realize that they posed questions and investigated the science that underlies a problem and used already existing technology (tools and materials) in order to imagine, design and construct the final solution to their problem. Student teams, prepare a power point which presents the whole process they followed in order to conclude and construct the final design.

❖ **Plenary**

The teacher initiates a discussion about how important it is to present your work in front of an audience. It is very important for an engineer to make a clear and comprehensible presentation to an audience who can easily be his/her employer. The teacher should point out that in order to explain something to others you must understand it in depth firstly. Have student teams to prepare a presentation where they explain what they did, how they worked and what the result was. The teacher motivates the audience to put forward questions:

- Did you find any difficulties in applying the Engineering Design Process? What difficulties did you face?
- Was the science background helpful in understanding how hydraulic arms work?
- Did you change your original design? What affect did this/these change(s) have upon the final design?
- Do the suggested materials work properly and safely? What materials you might substitute?
- What changes did you make to your design in order to improve its performance?
- How would you change your design if you had to lift heavier objects?
- If you had more time what you would add, change, or do differently?

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If you can't explain it simply, you don't understand it well enough. (Albert Einstein).

Construction Instructions

<u>Materials</u>

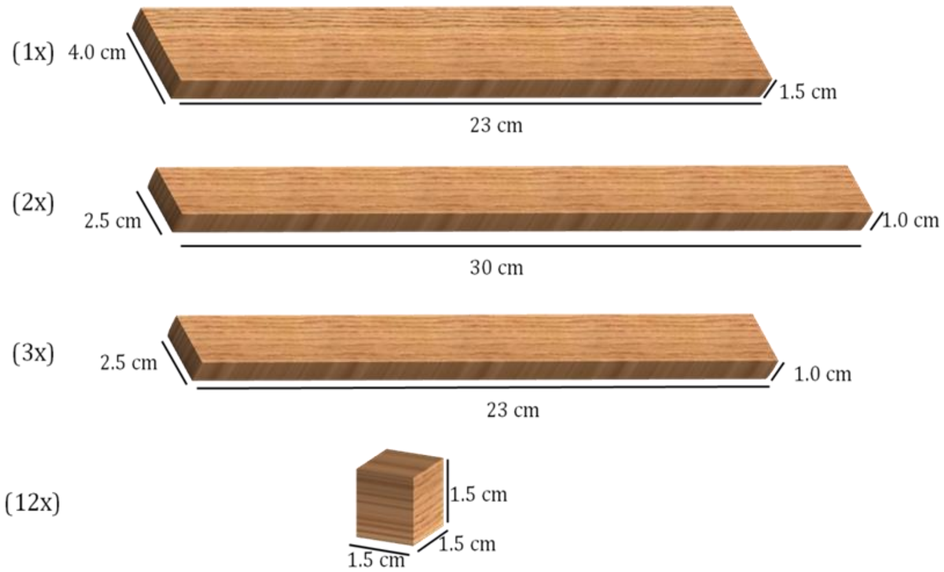

Figure 6: Plywood

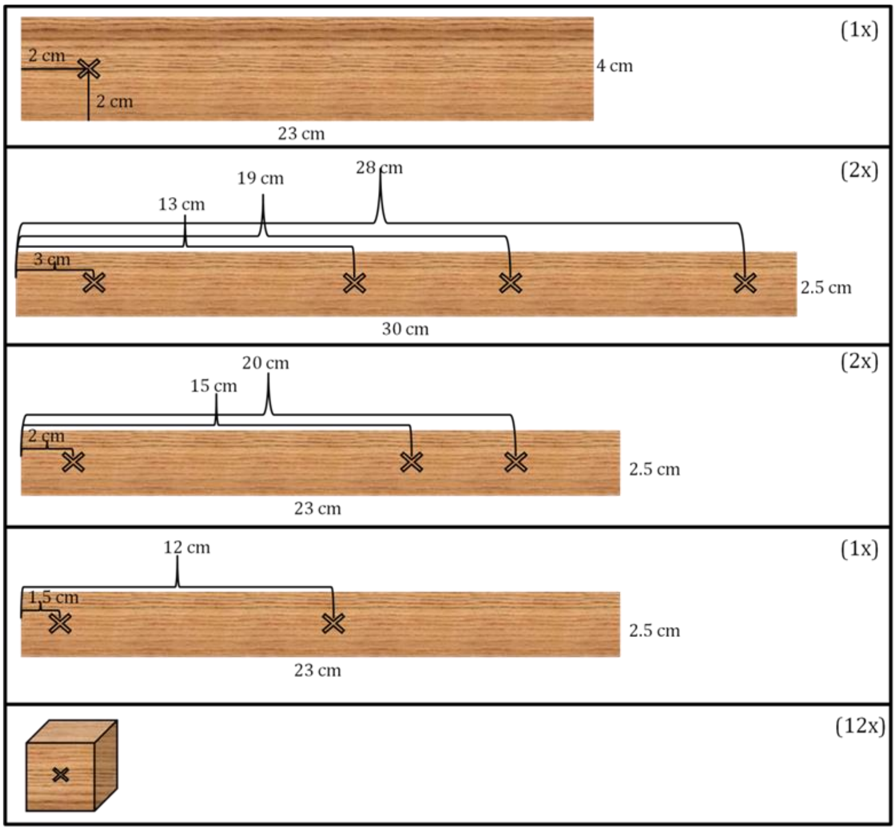

Figure 7:Drill holes as marked in the figure

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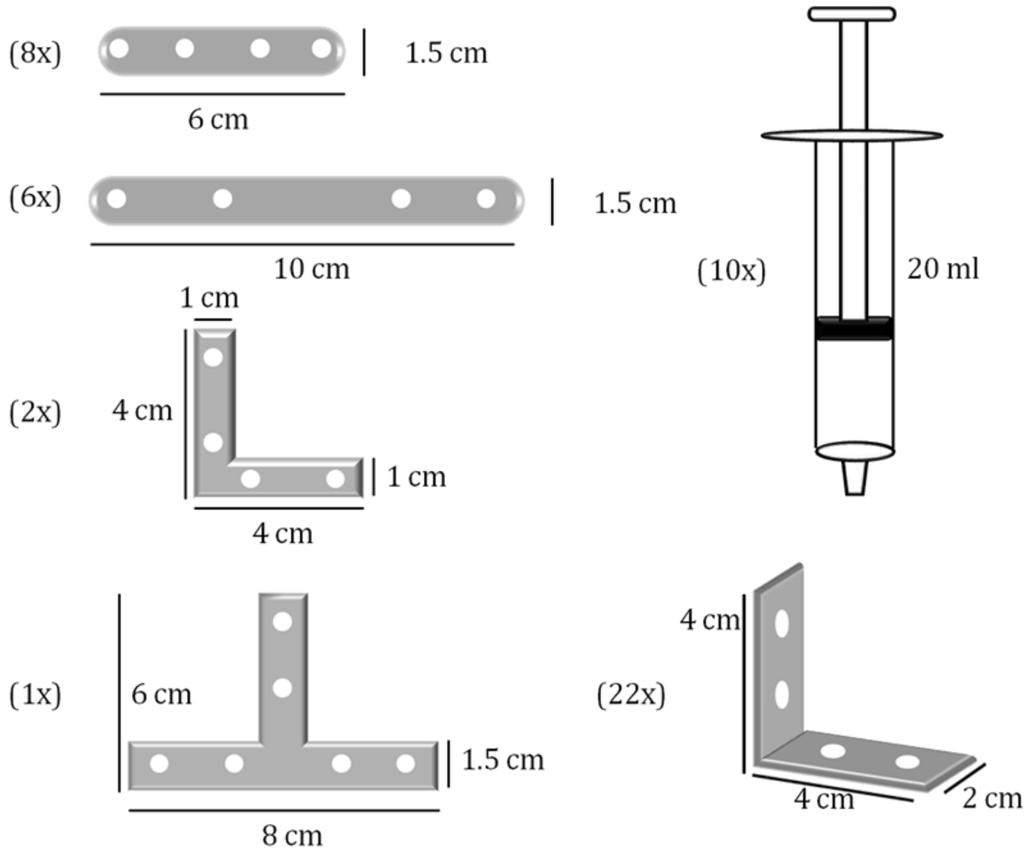

Figure 8: Steel Joints

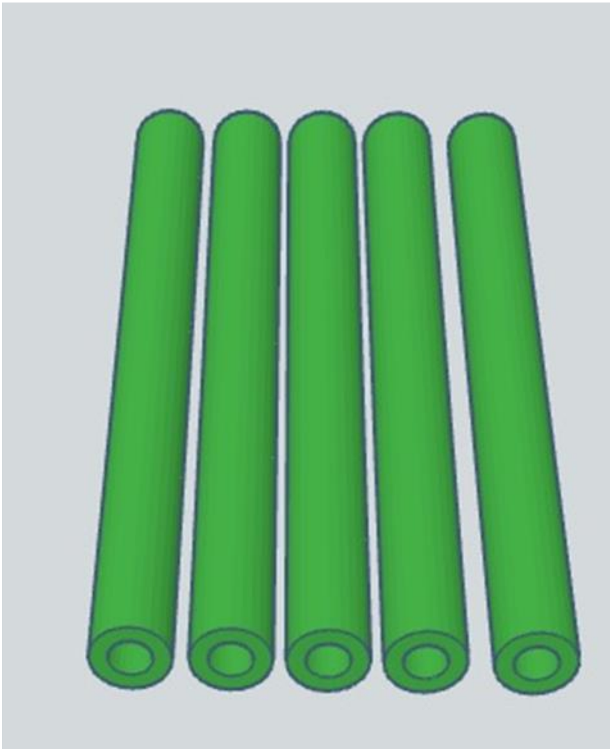

Figure 9: PVC Pipes

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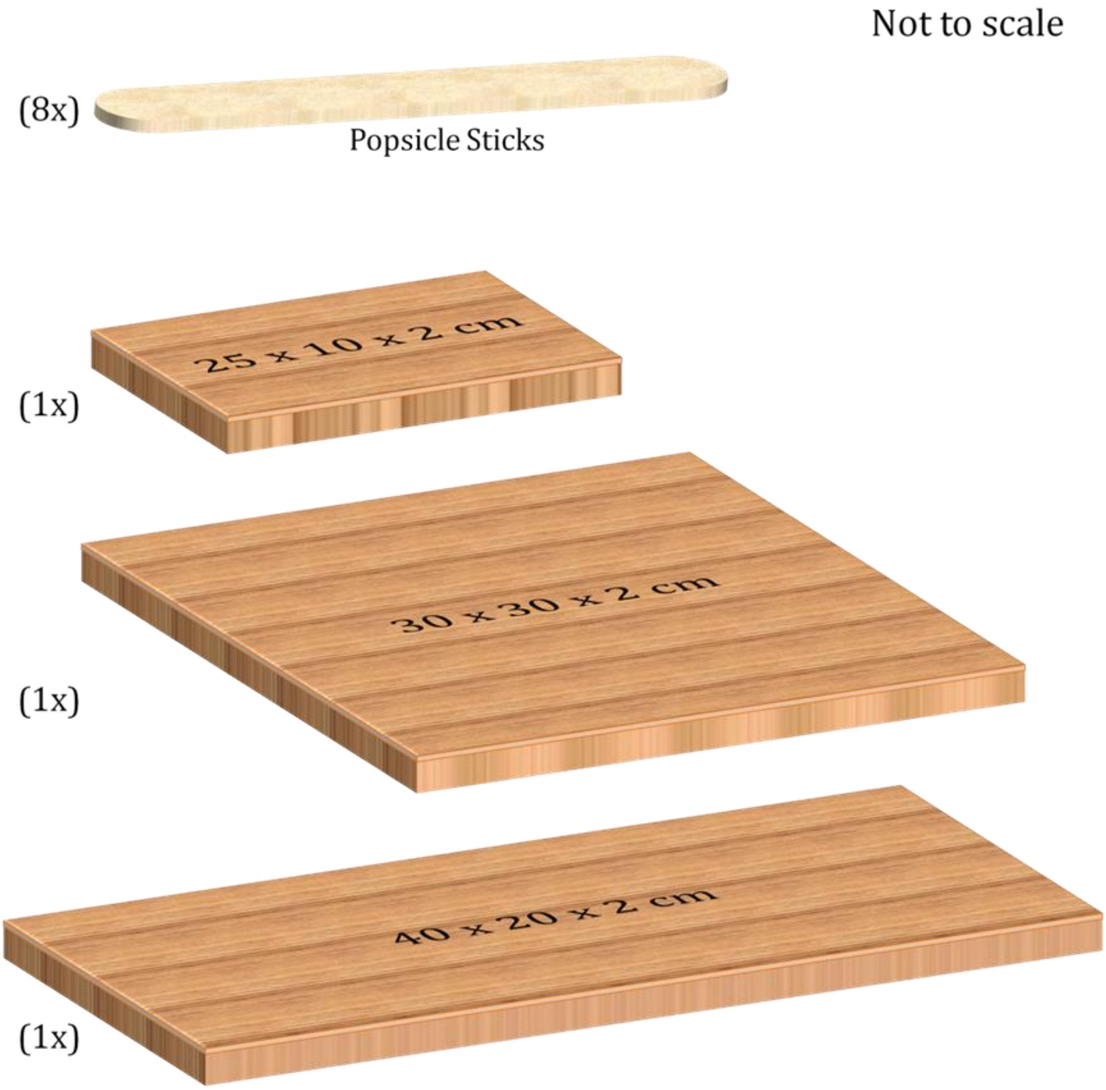

Figure 10

You will also need:

- screws, and corresponding nuts and washers
- screwdrivers
- pliers
- electric drill
- 5 meters of silicon rubber tube that fits in the syringe's hose
- 20 tie wraps (or zip ties)
- 20 cm of tensile steel wire
- a glue gun

<u>**The main body**</u>

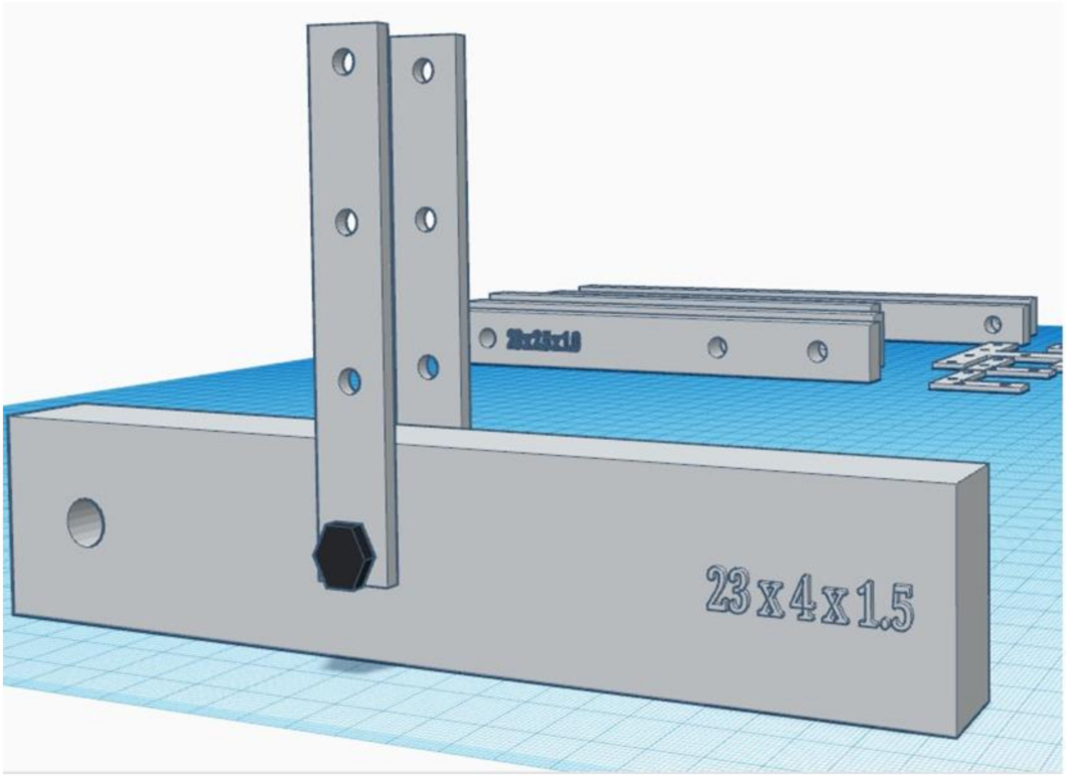

Figure 11

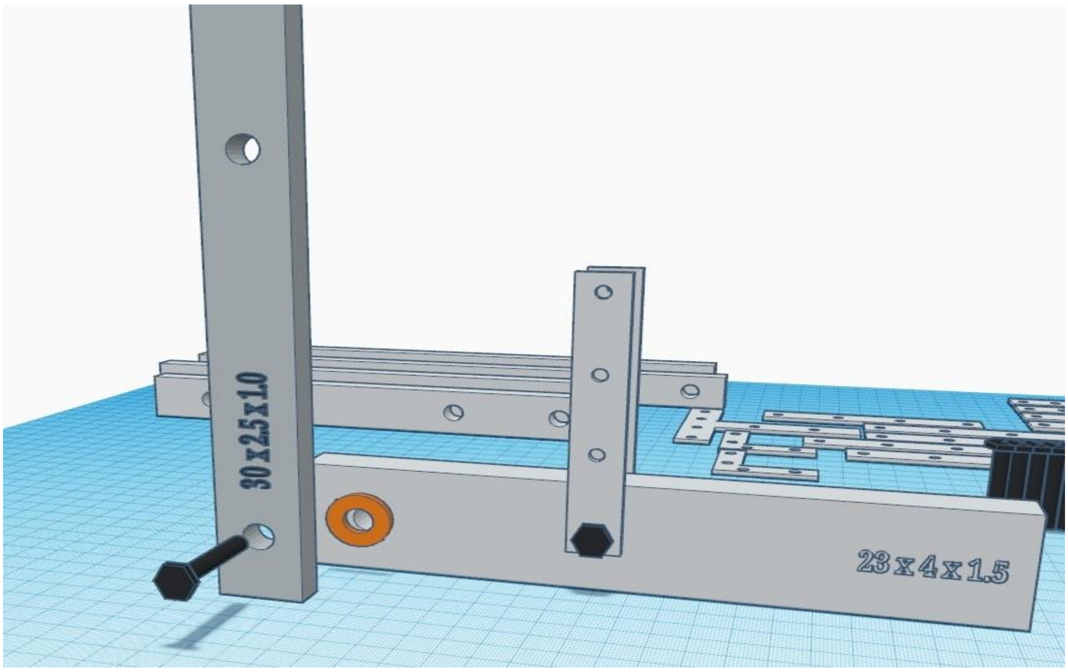

Figure 12

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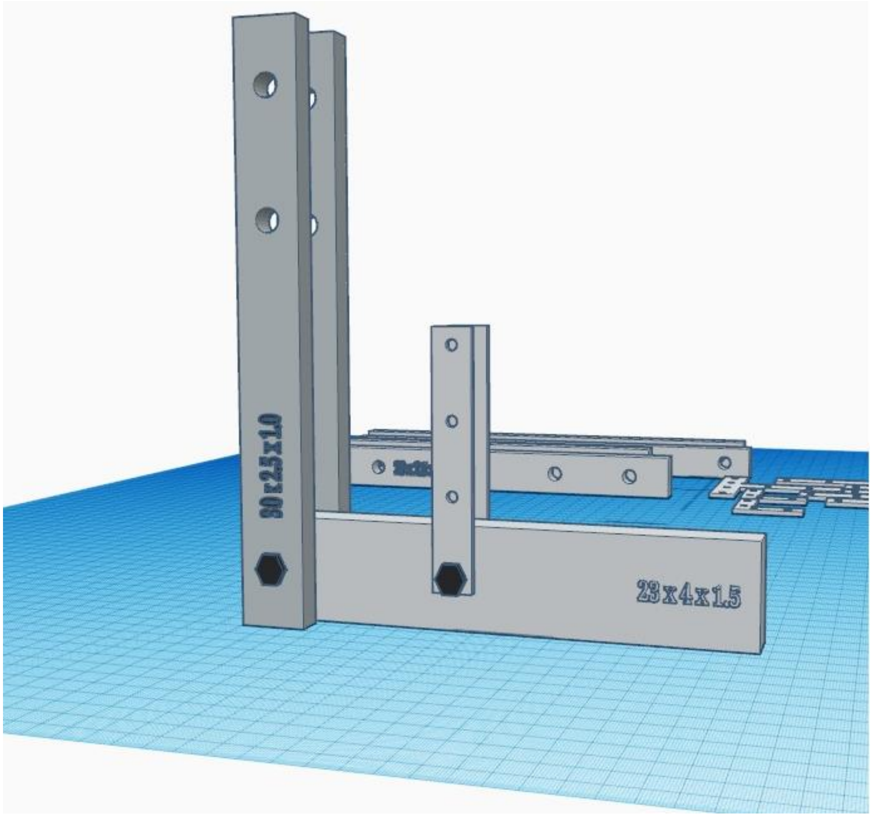

Figure 13

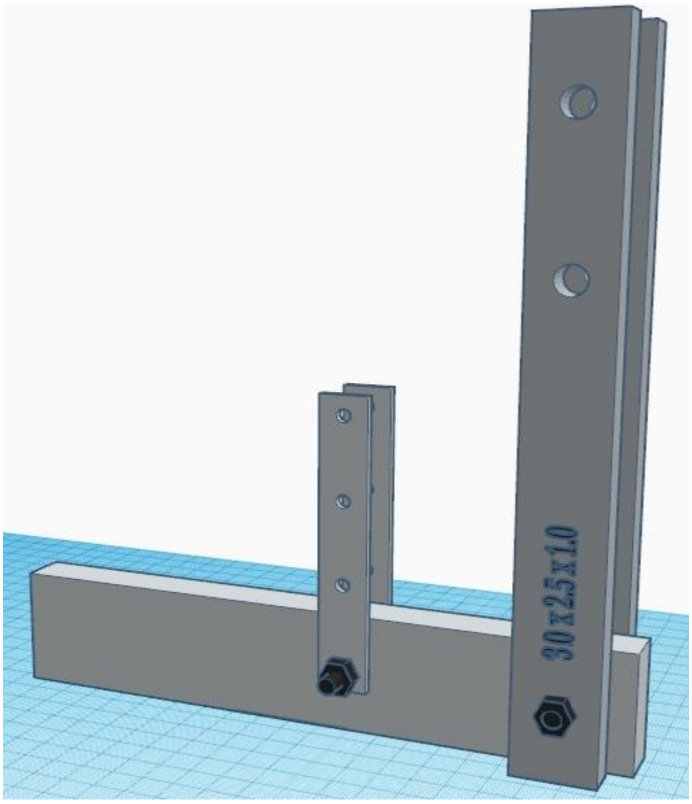

Figure 14

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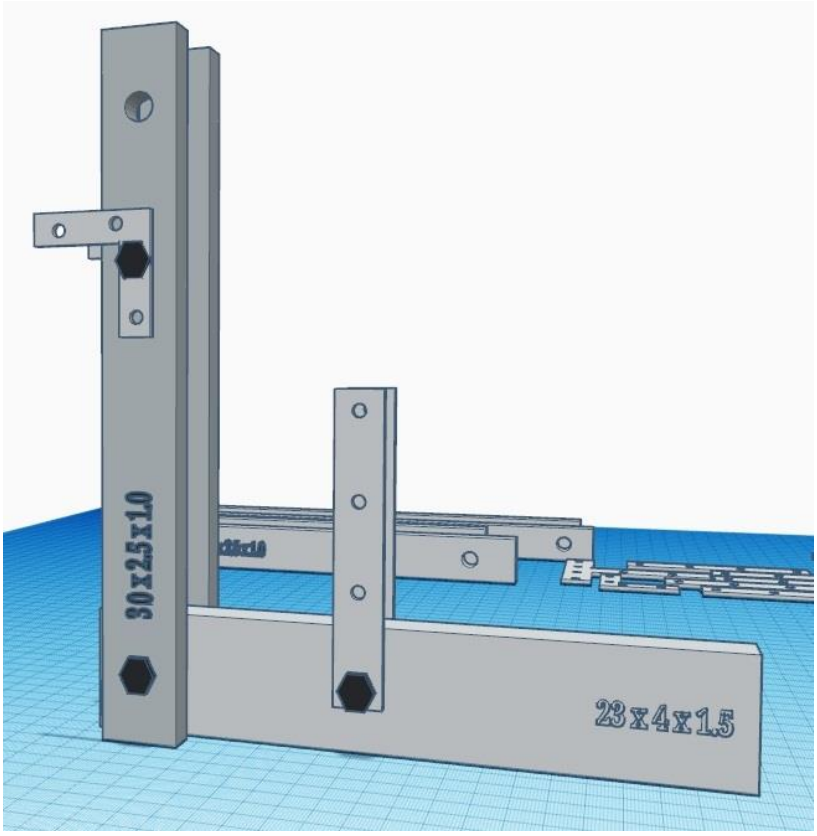


Figure 15

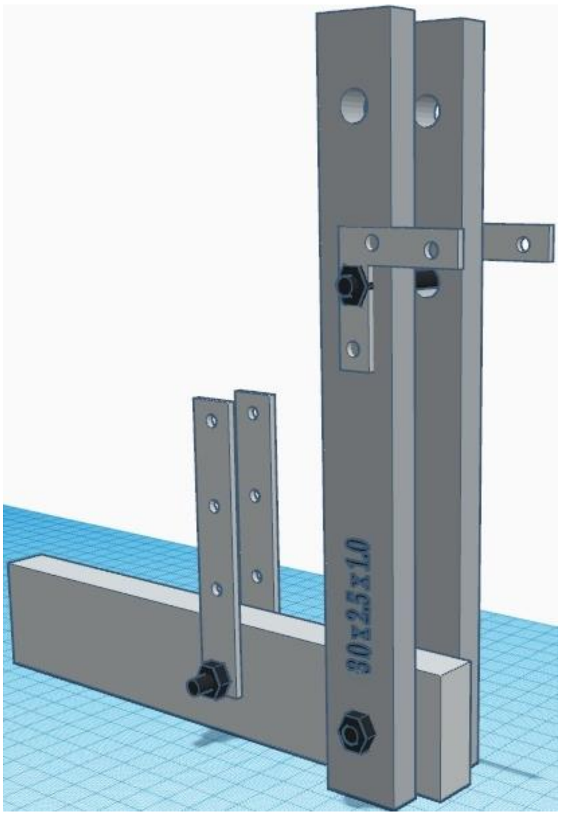
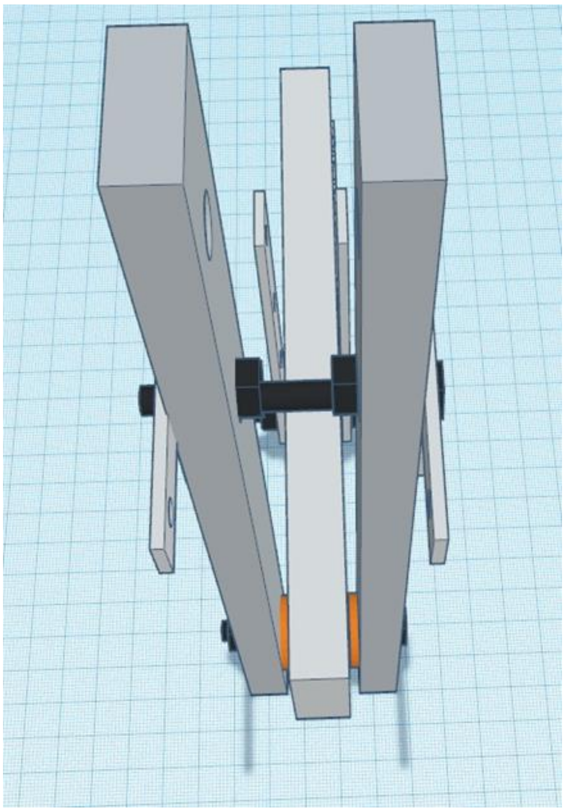


Figure 16



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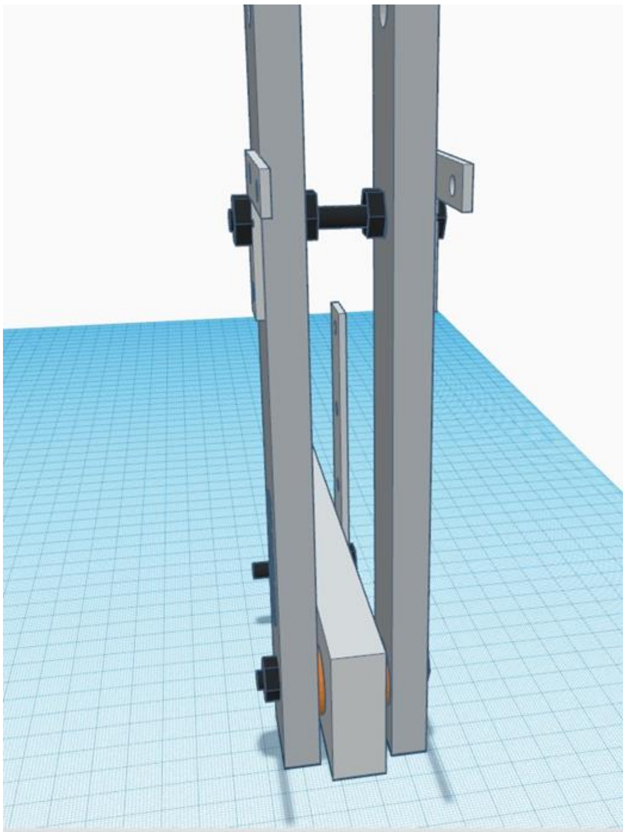

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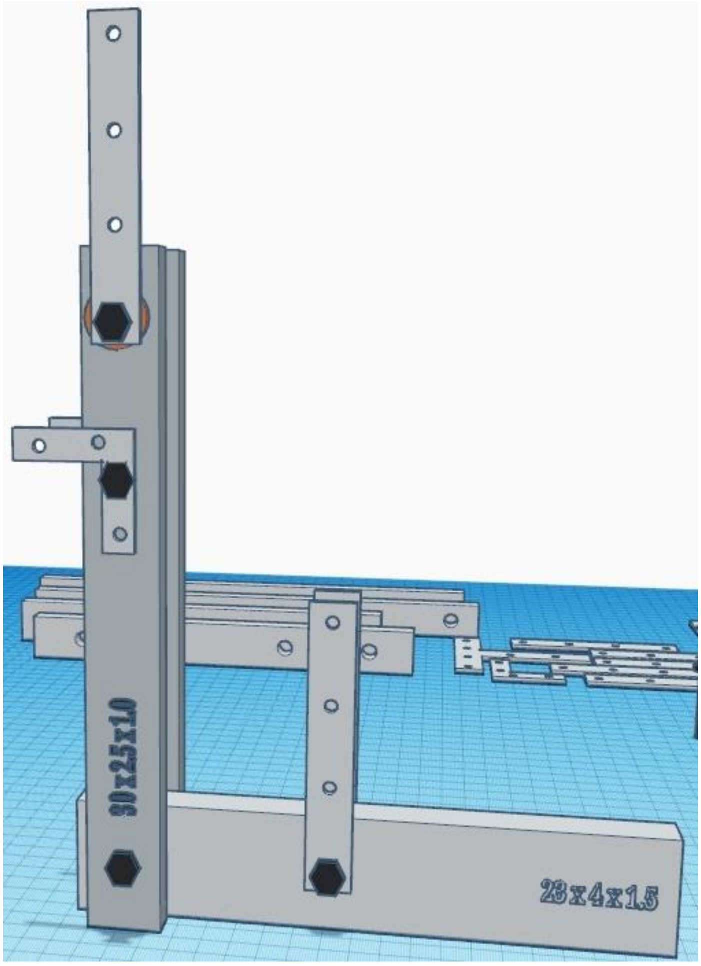

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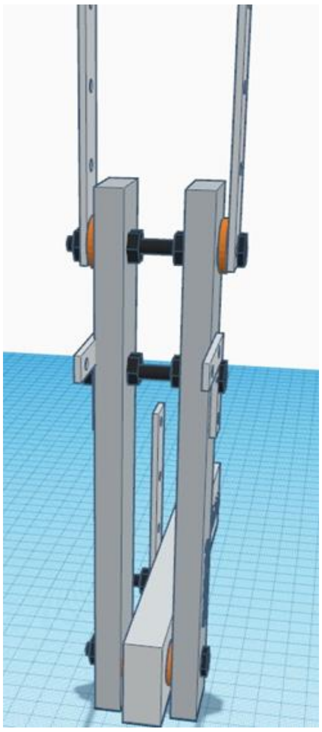

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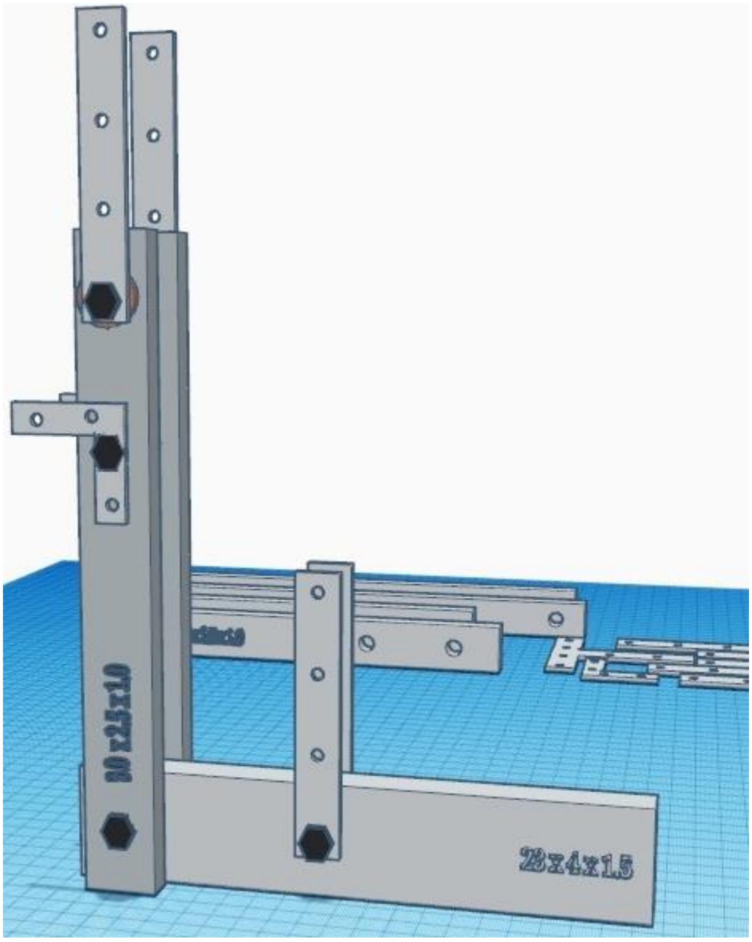
Figure 20



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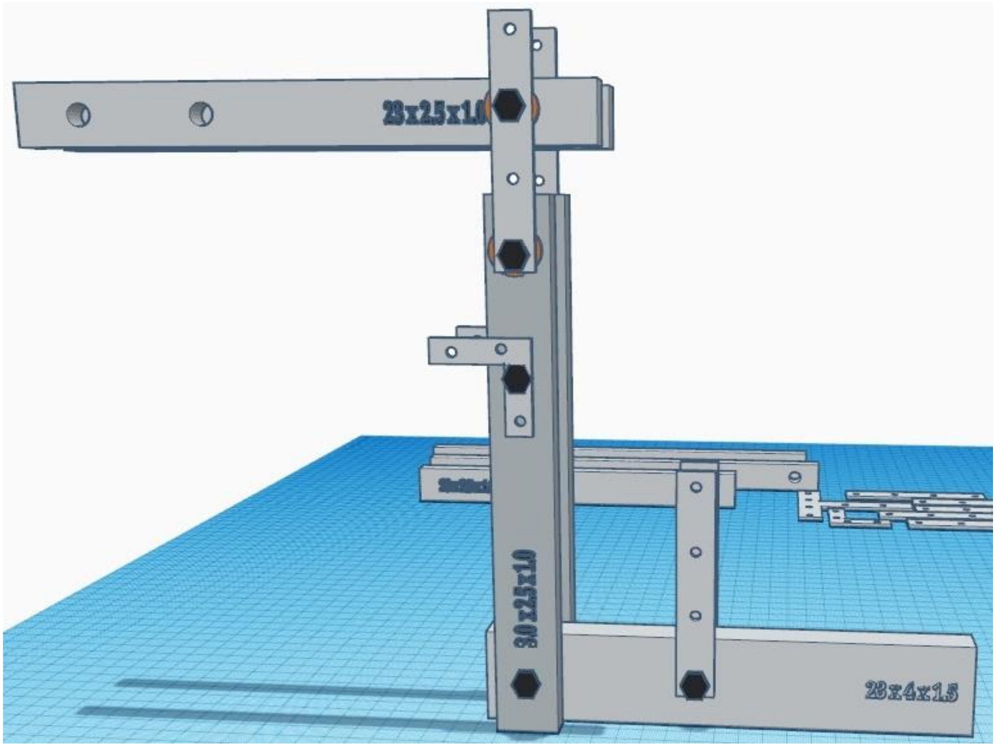

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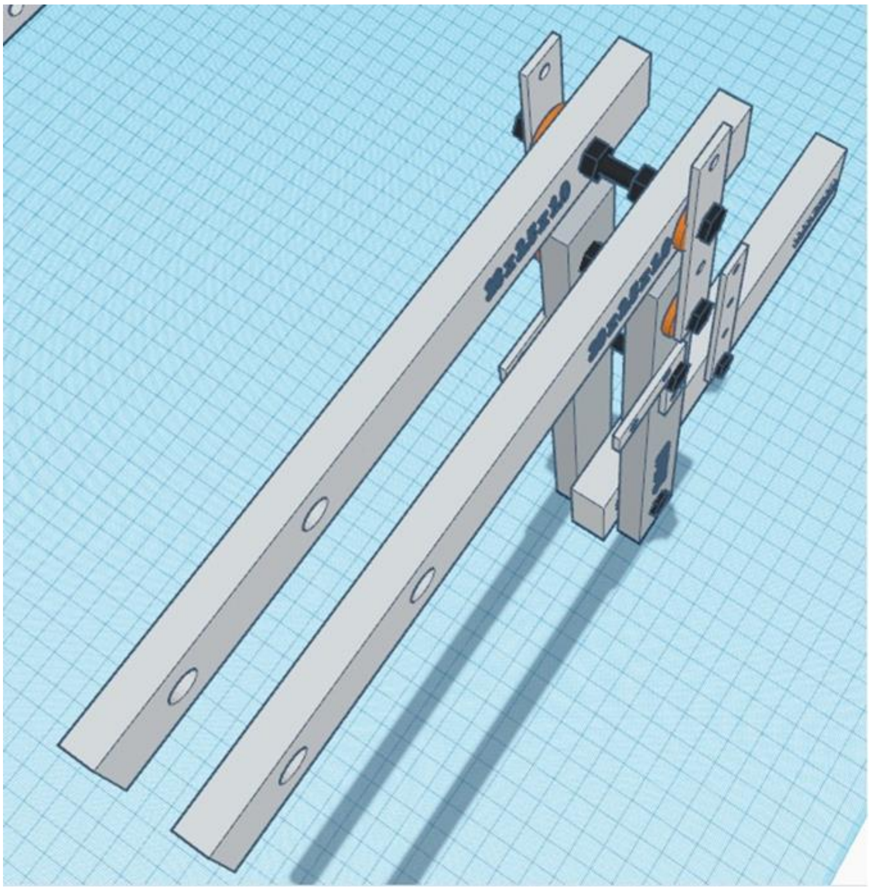

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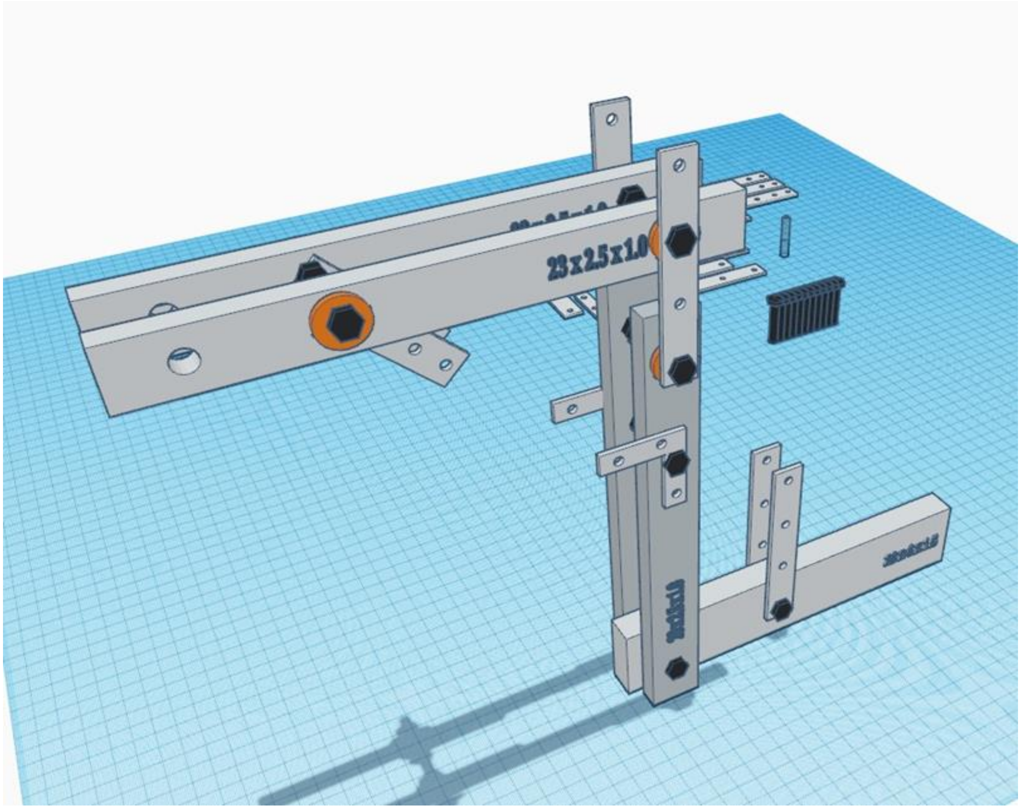

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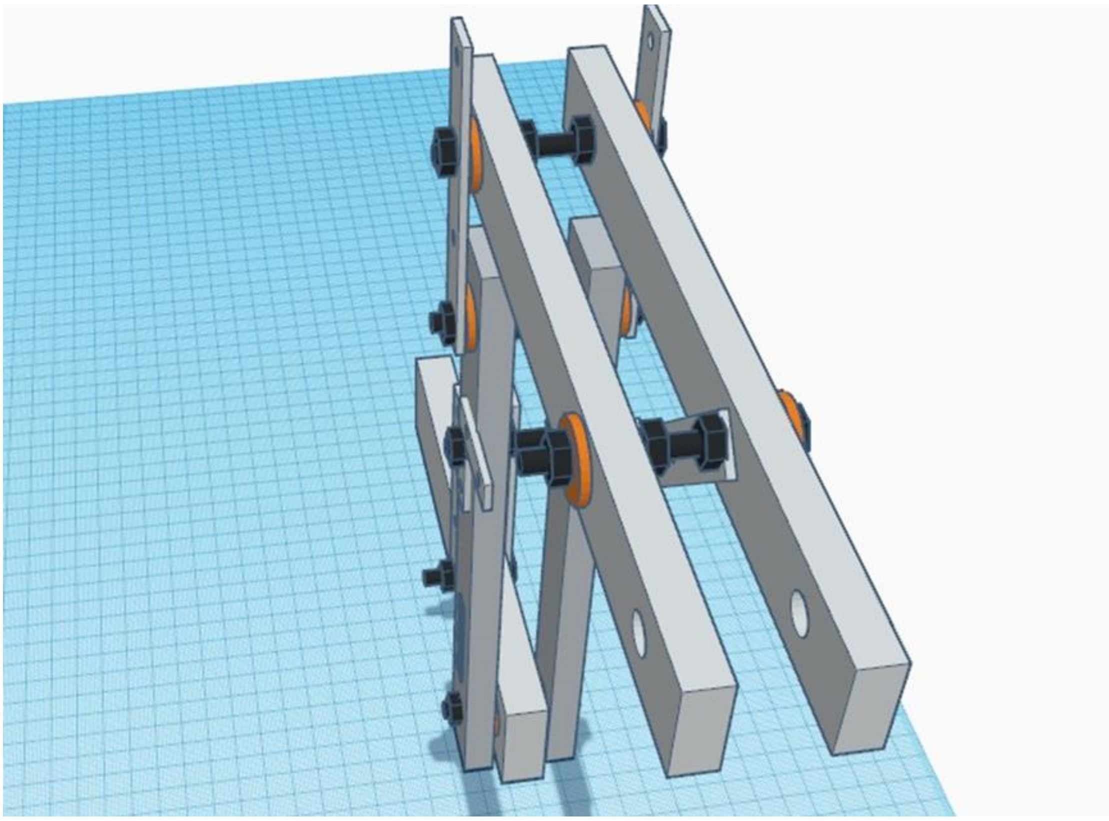

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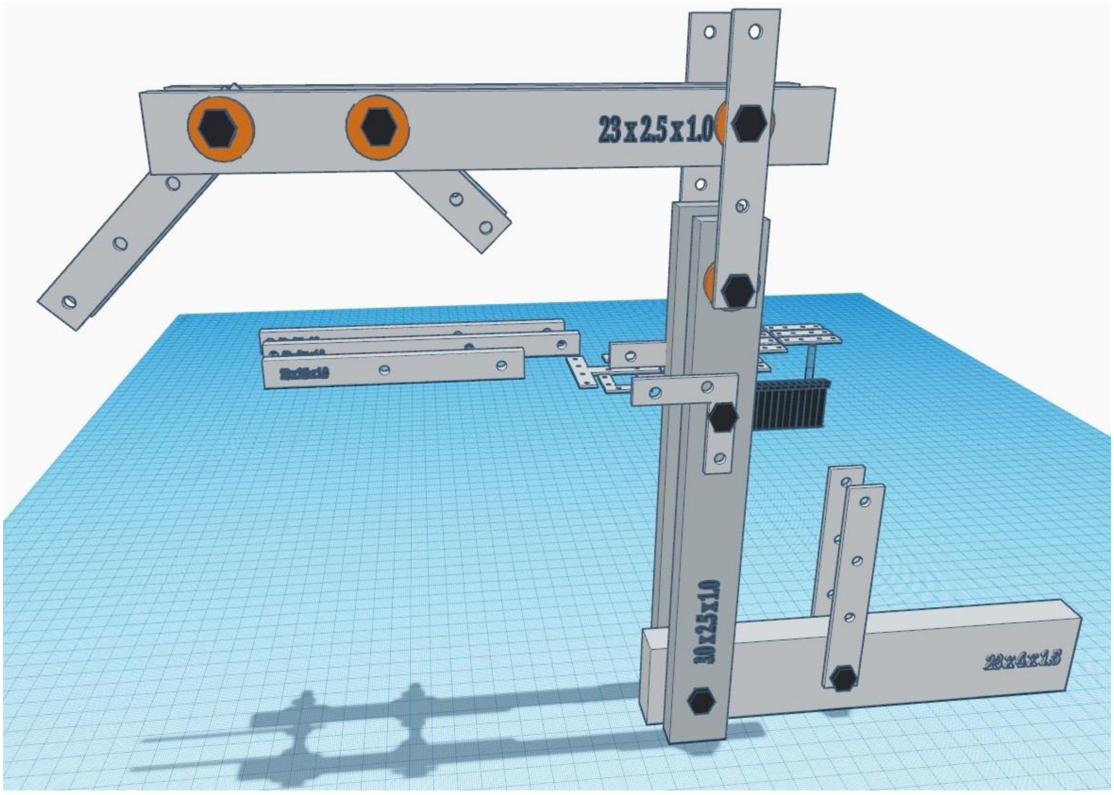

Figure 26

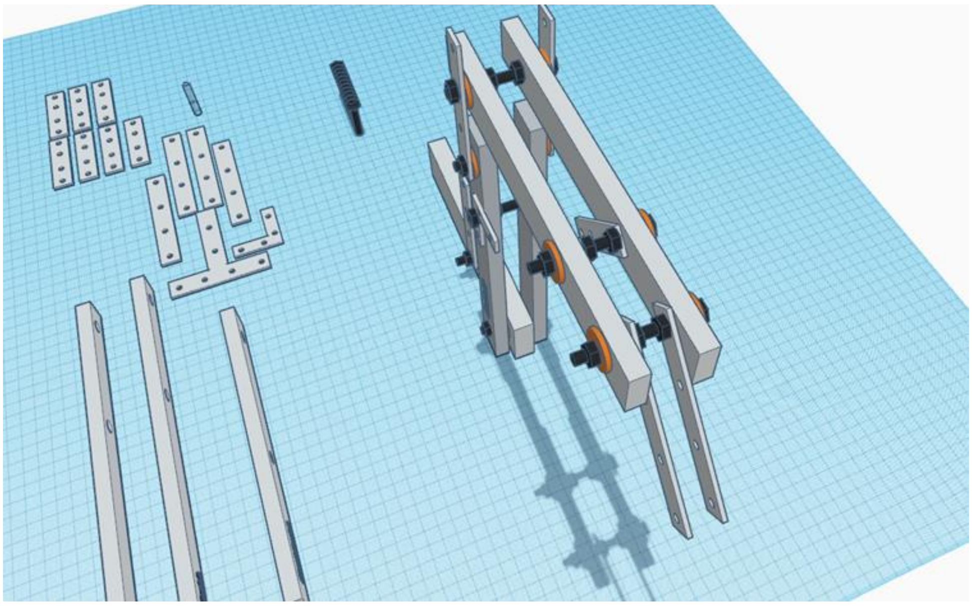

Figure 27

<u>The gripper</u>

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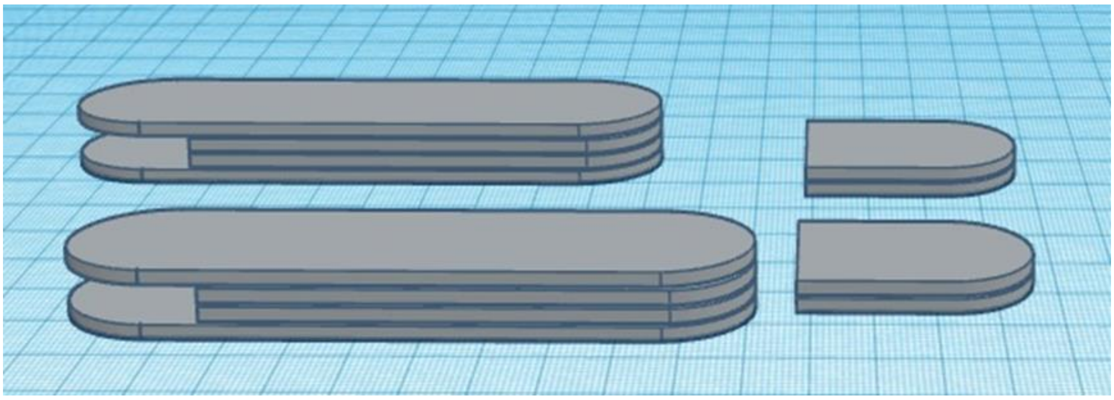
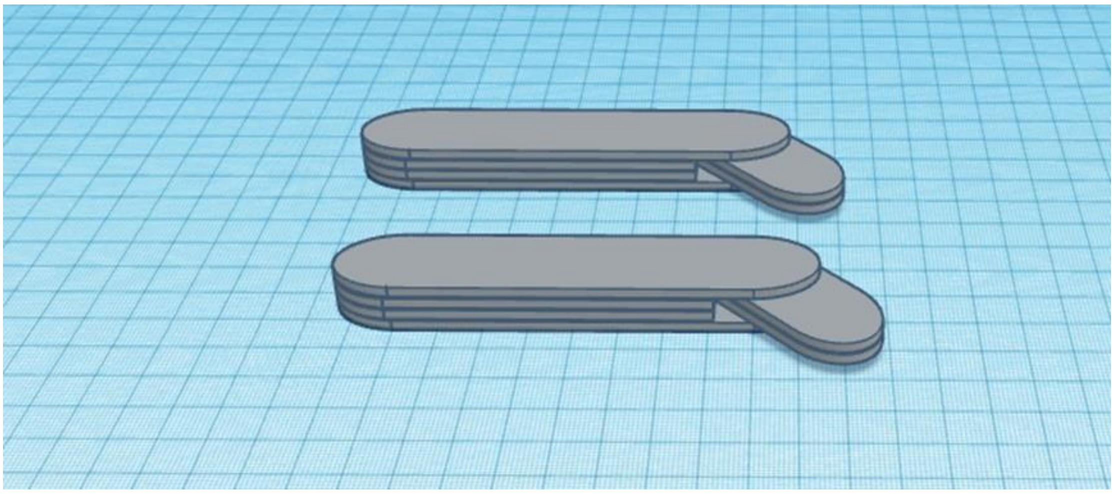


Figure 28



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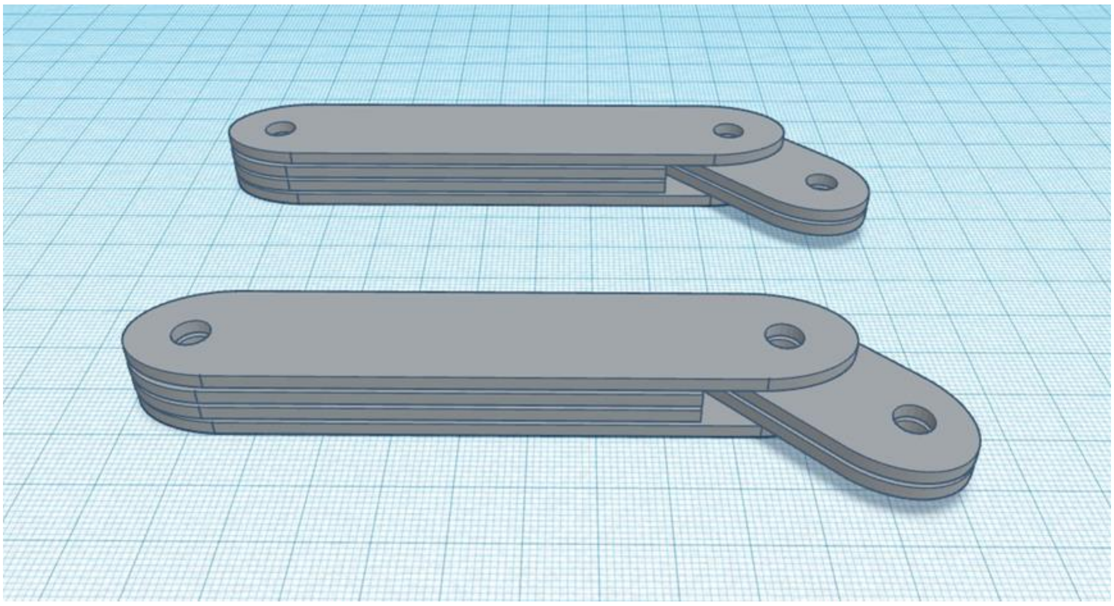
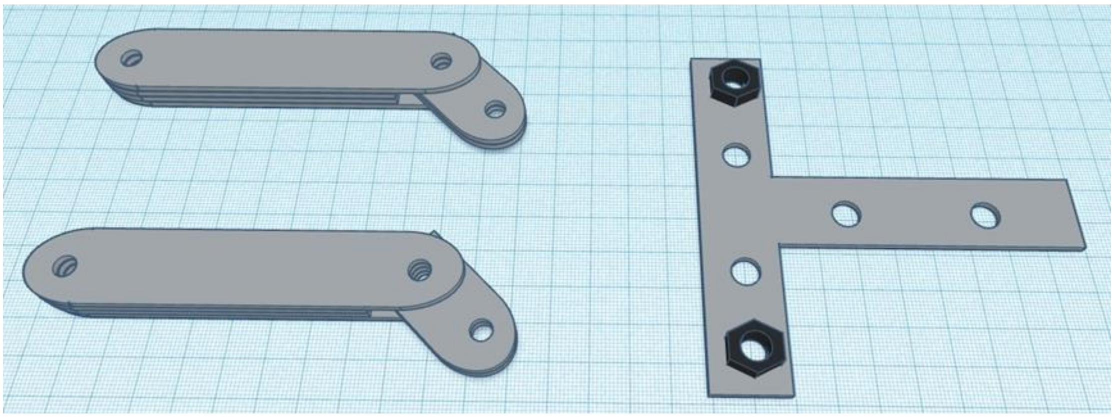


Figure 30



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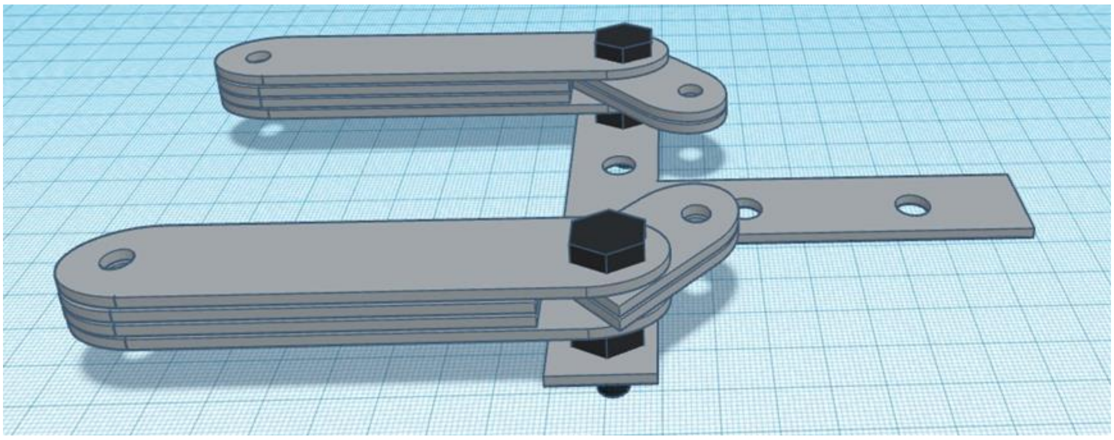

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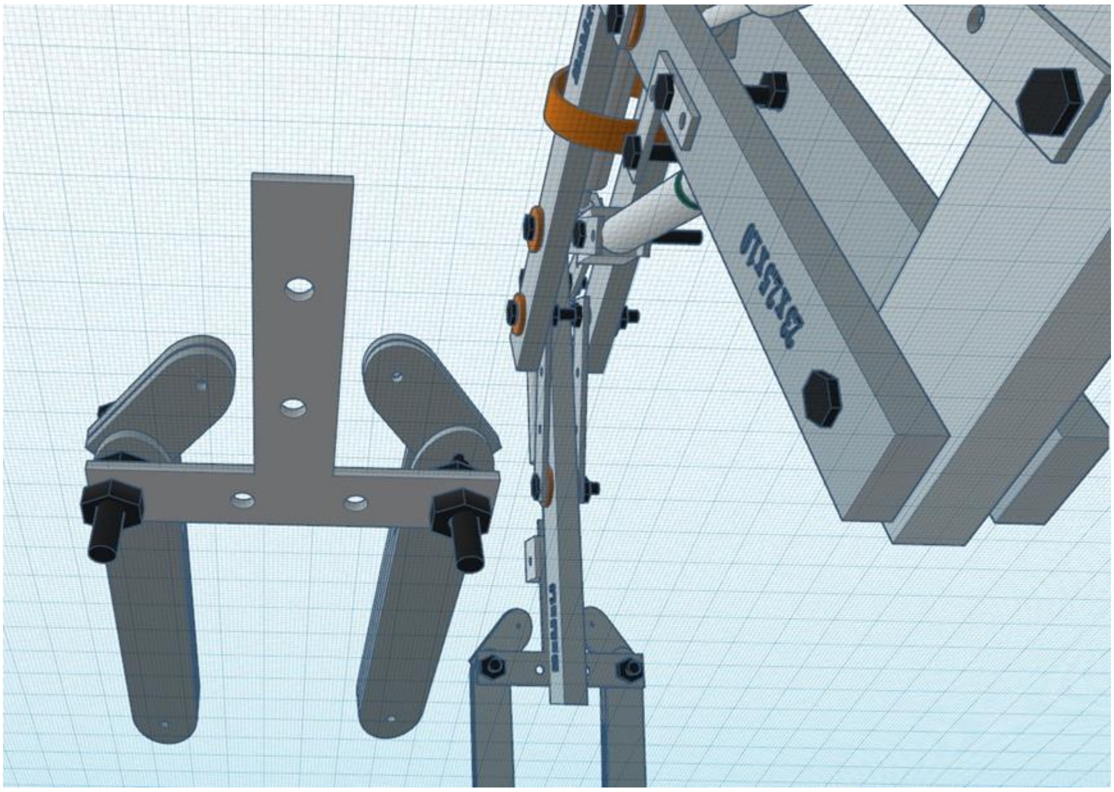

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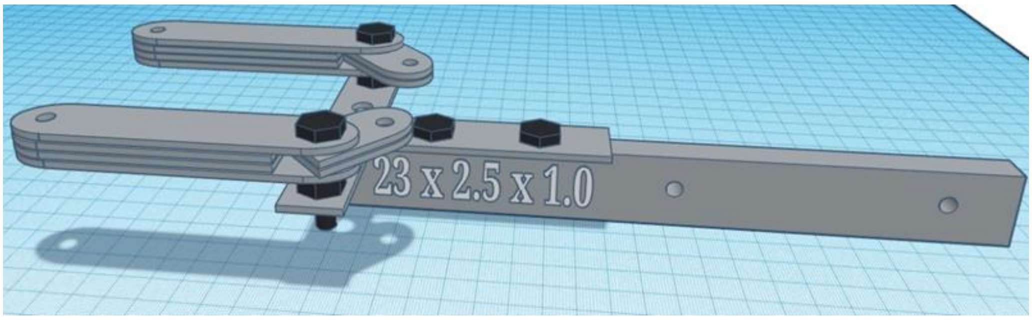
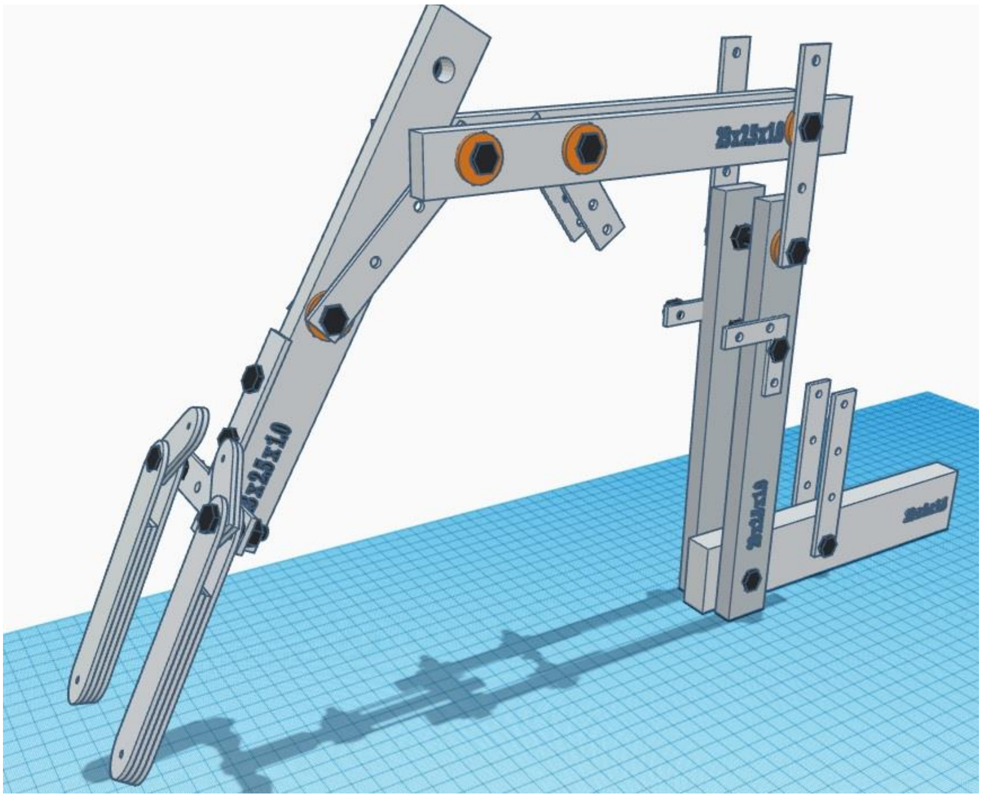


Figure 34

Arm + Gripper



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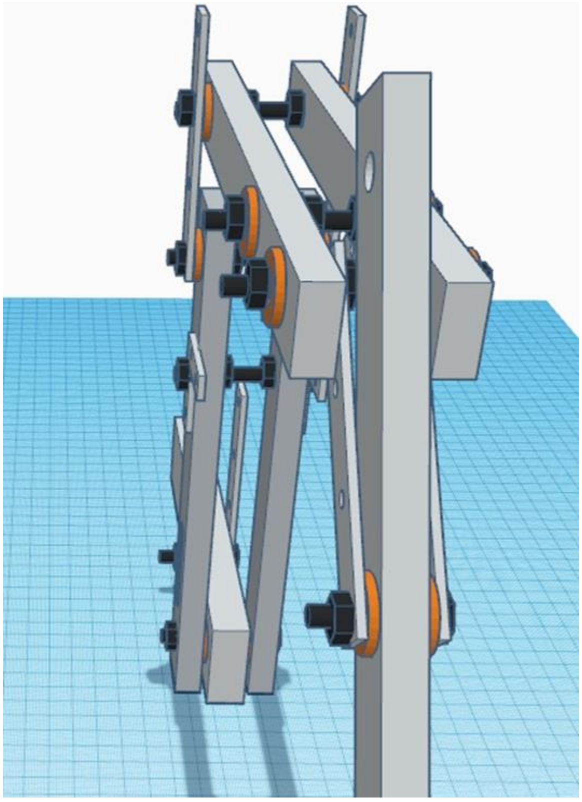

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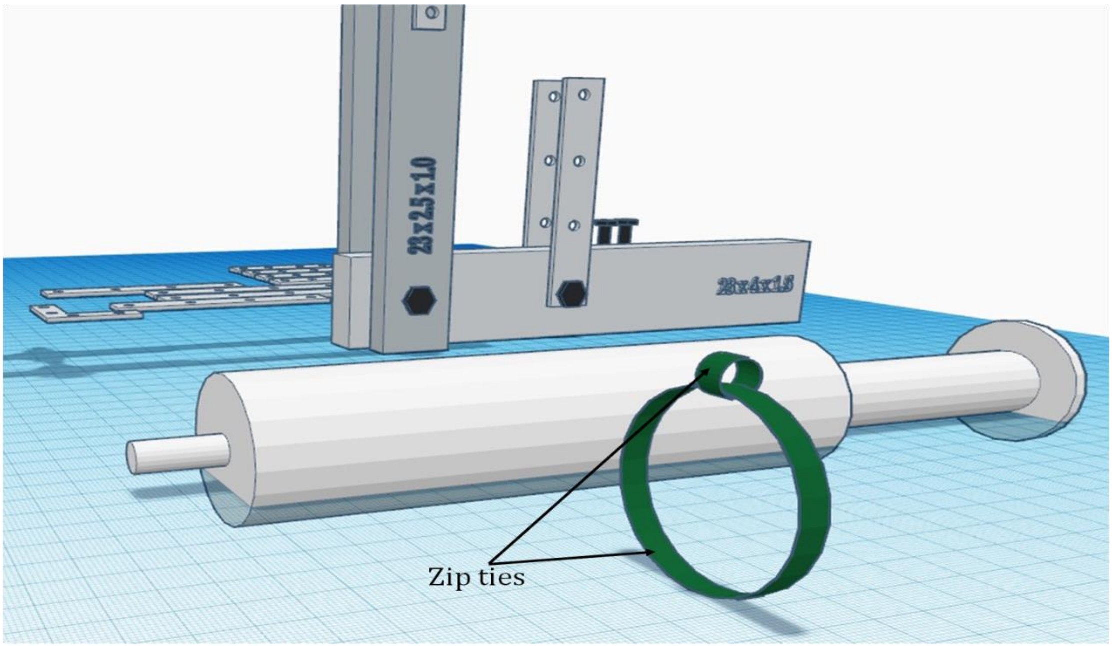

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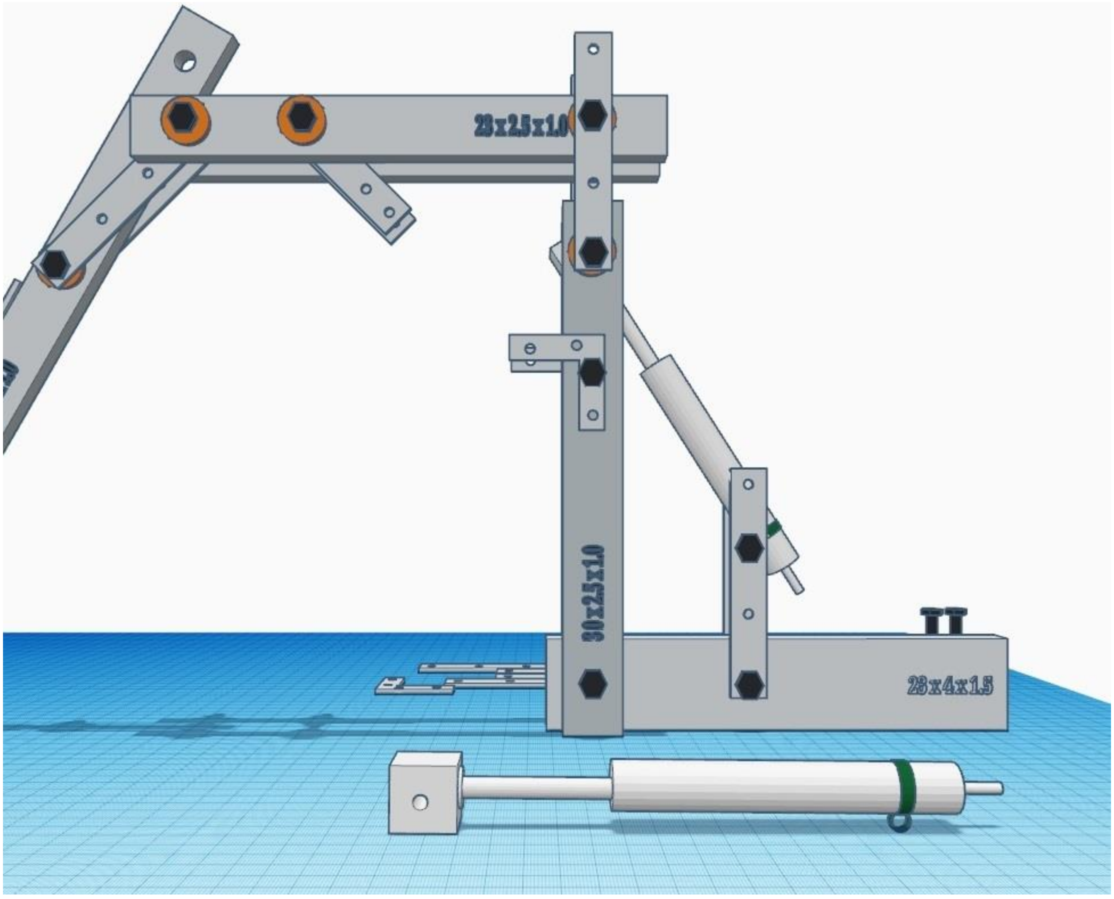


Figure 38: Using the glue gun, glue the wooden block to the syringe's plunger

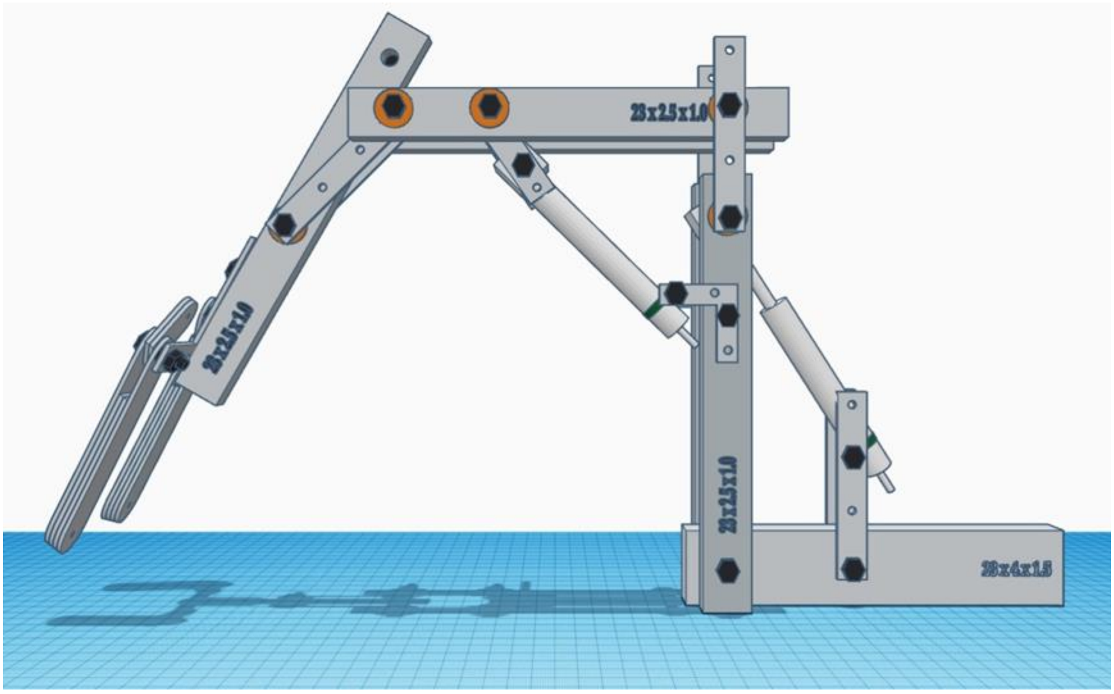
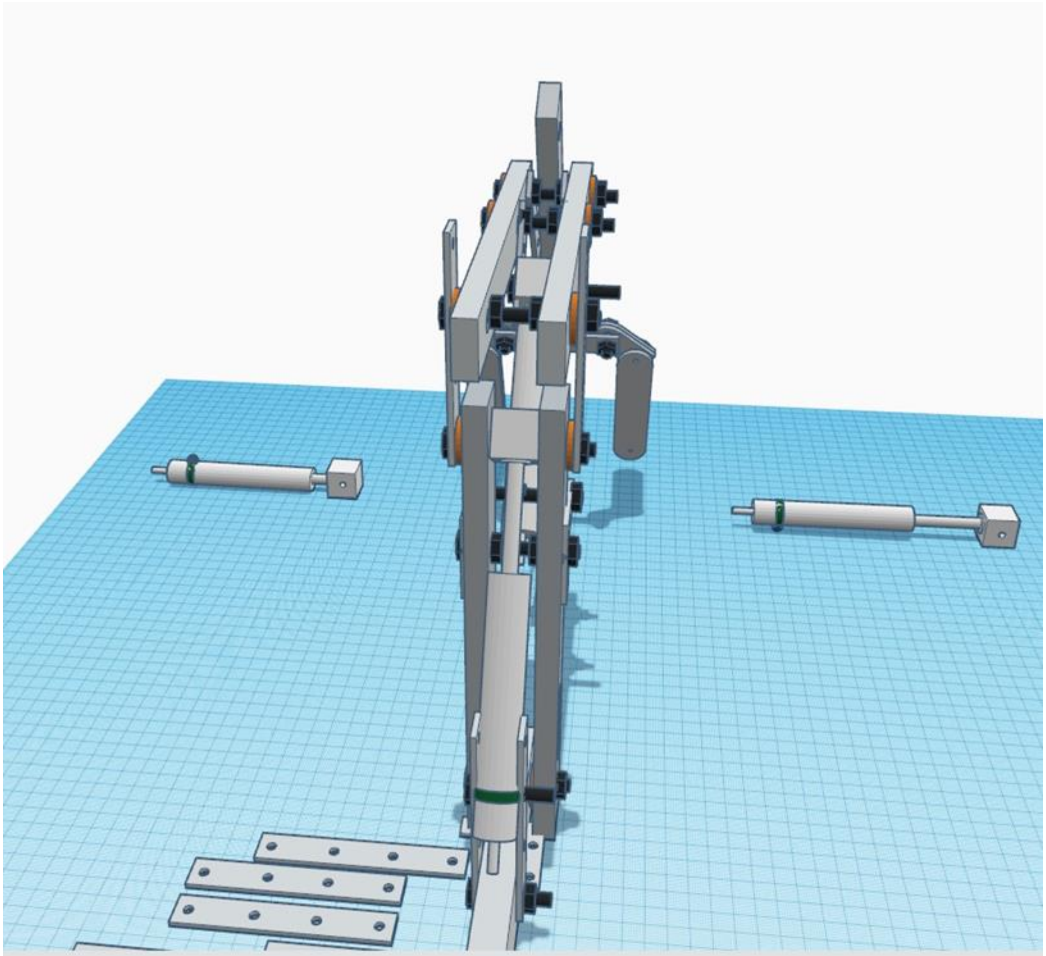


Figure 39



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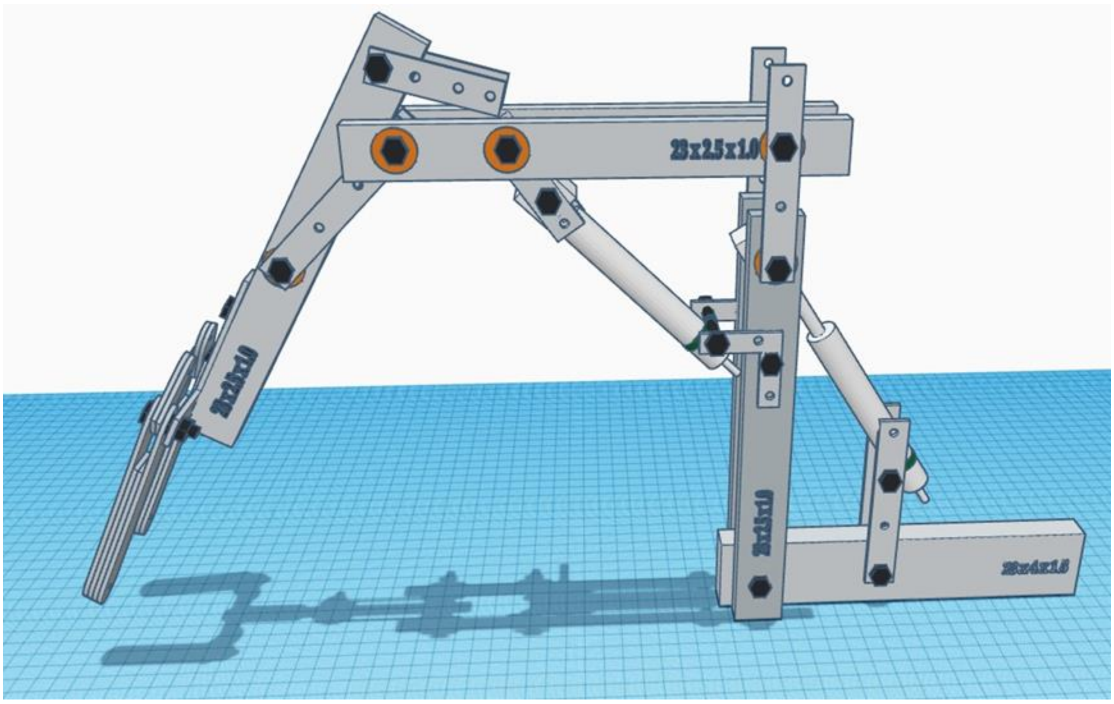

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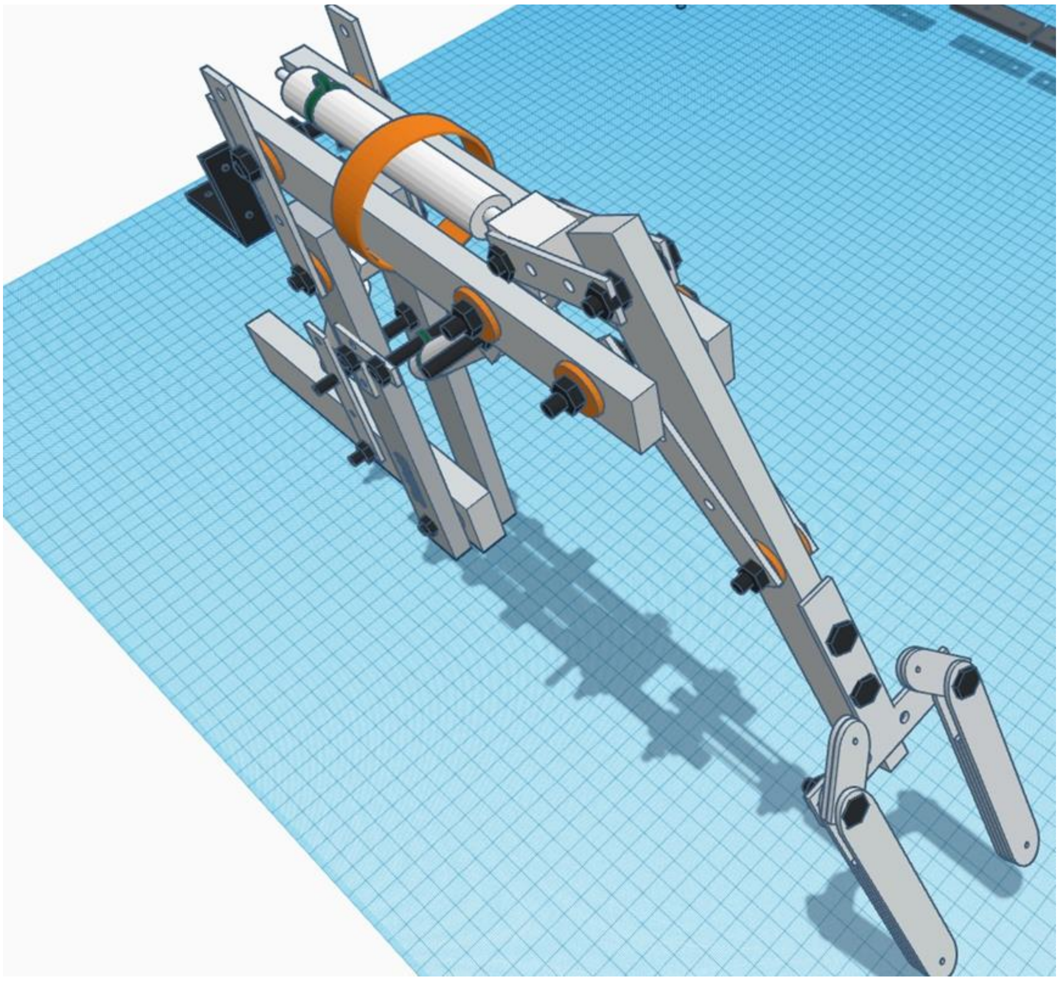

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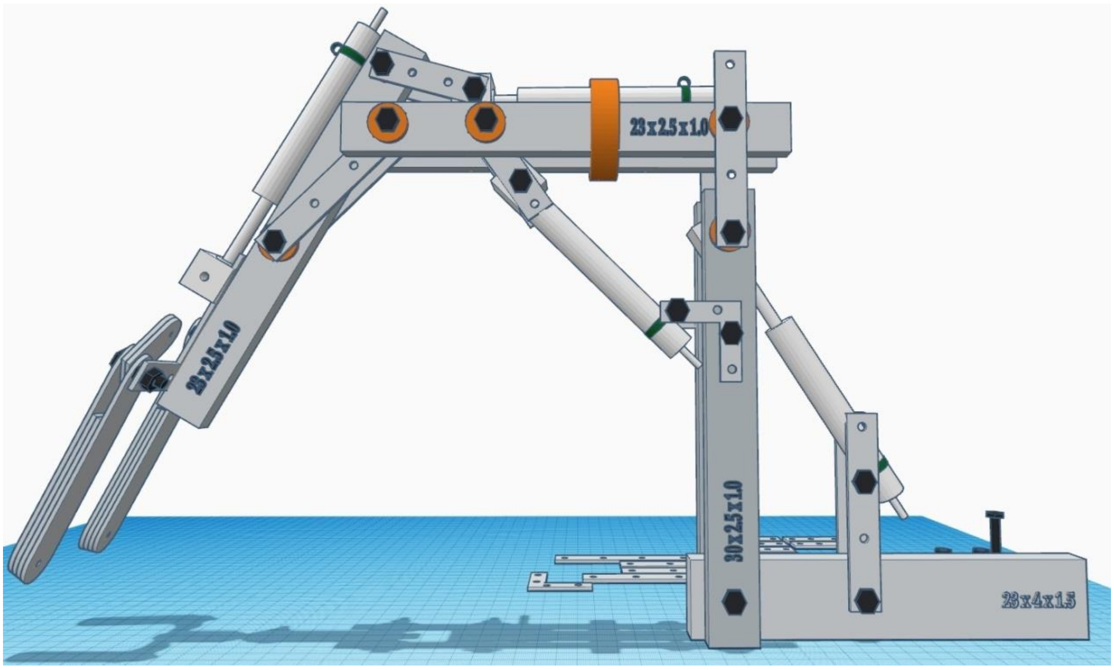

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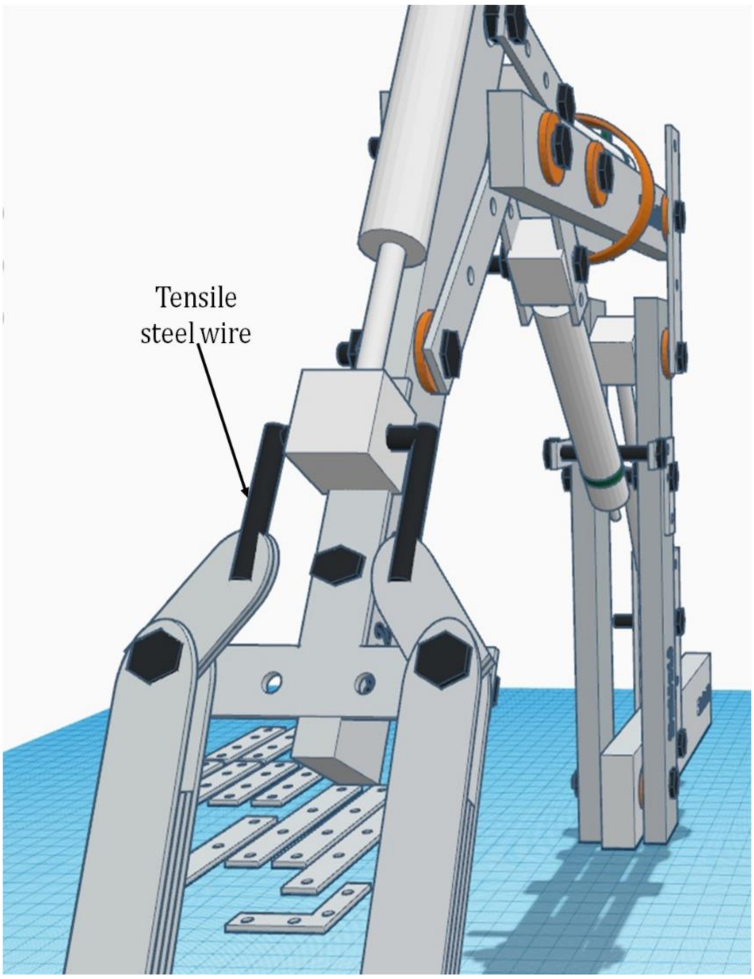

Figure 44

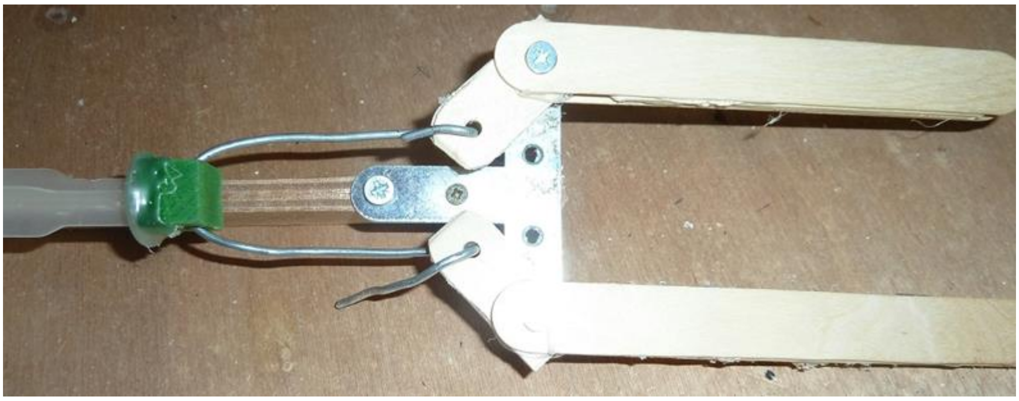

Figure 45

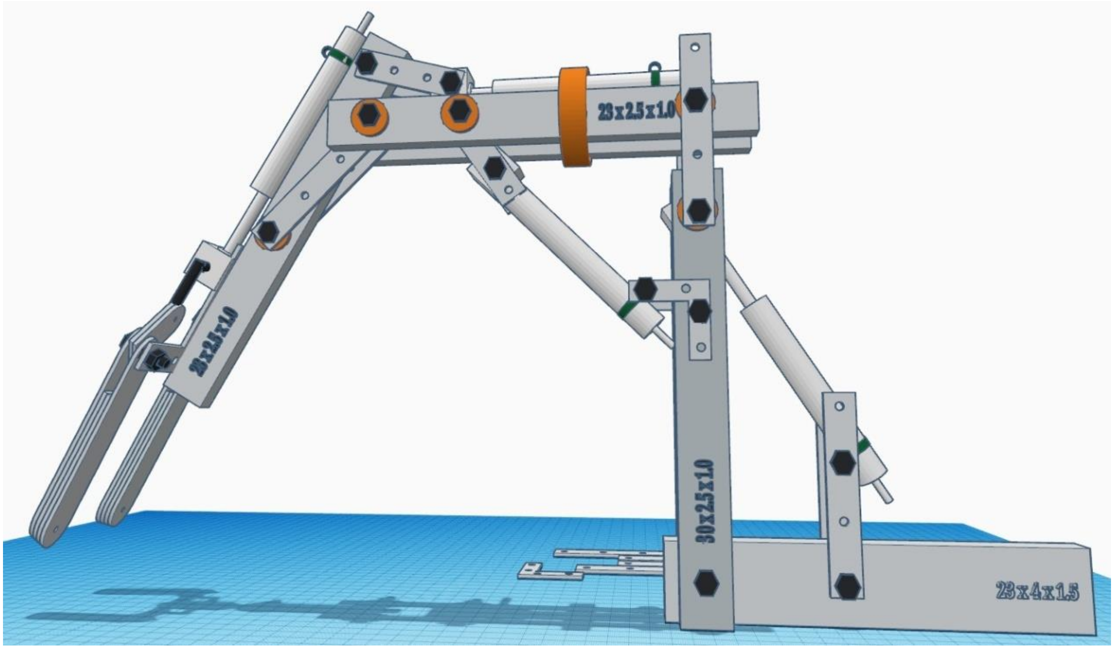

Figure 46

The base

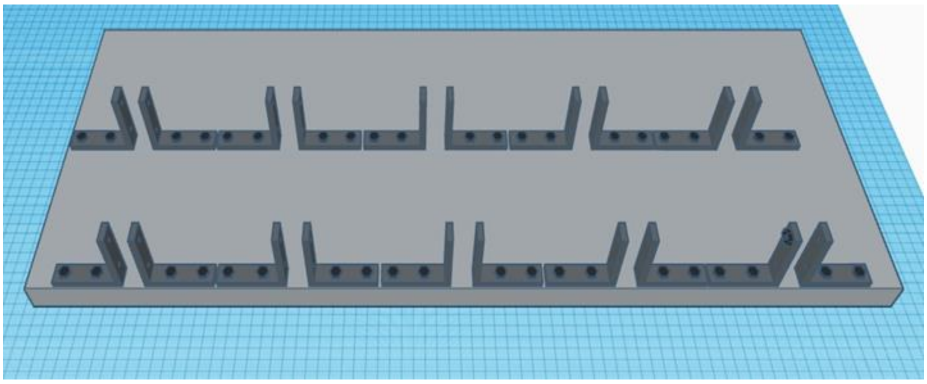

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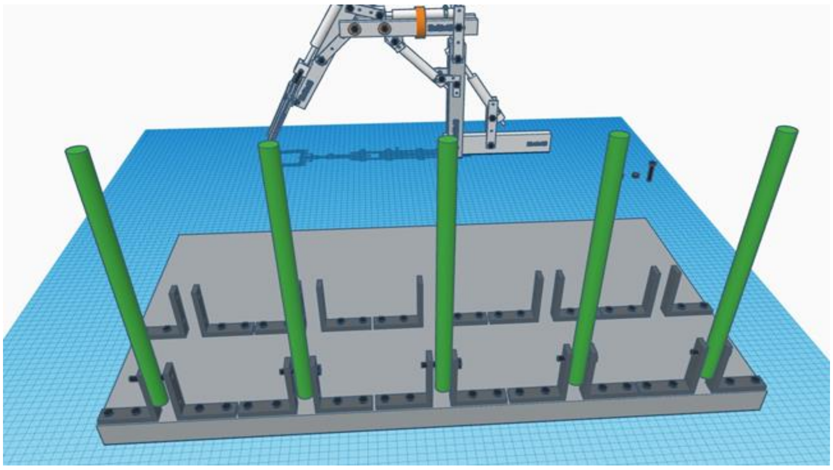
Figure 47



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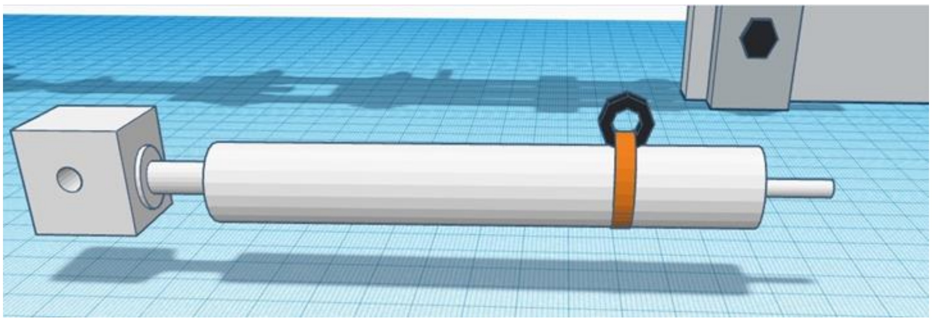

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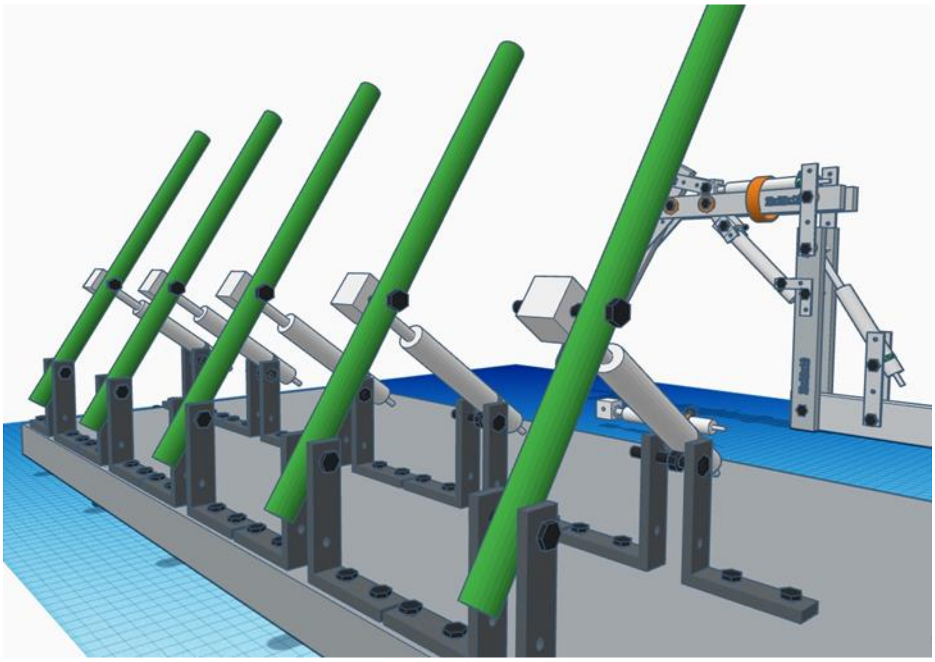
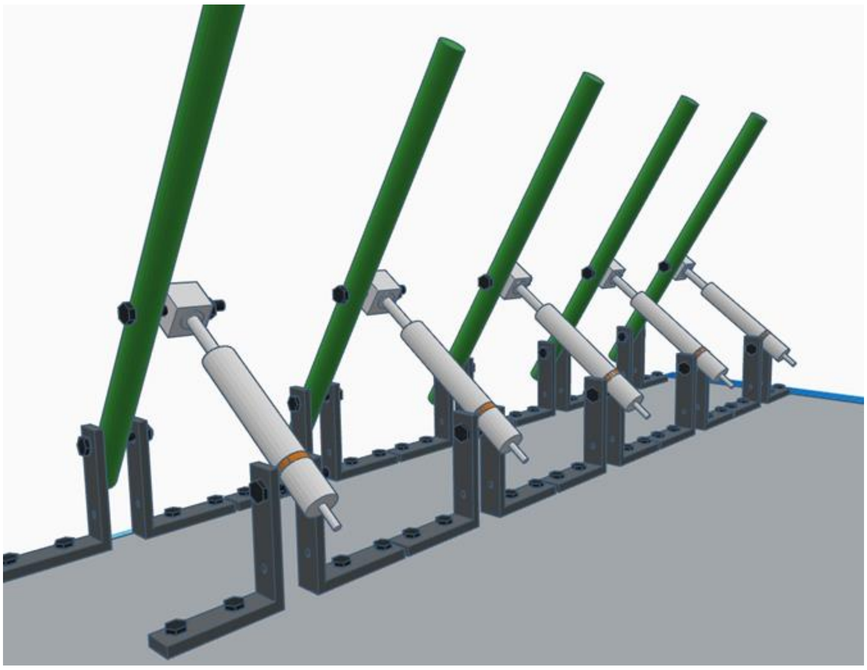


Figure 50



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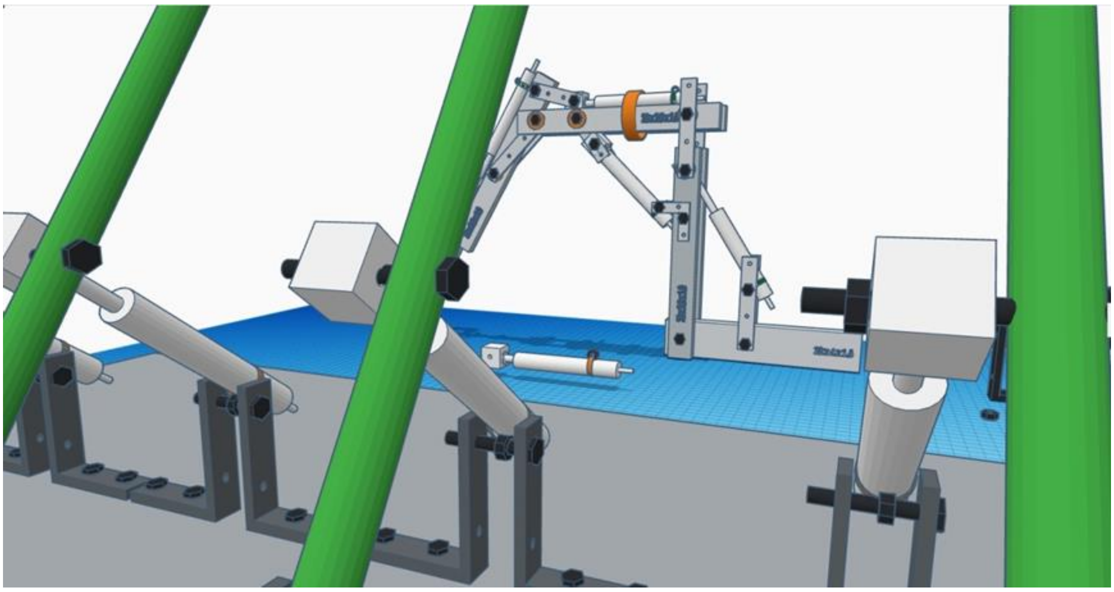

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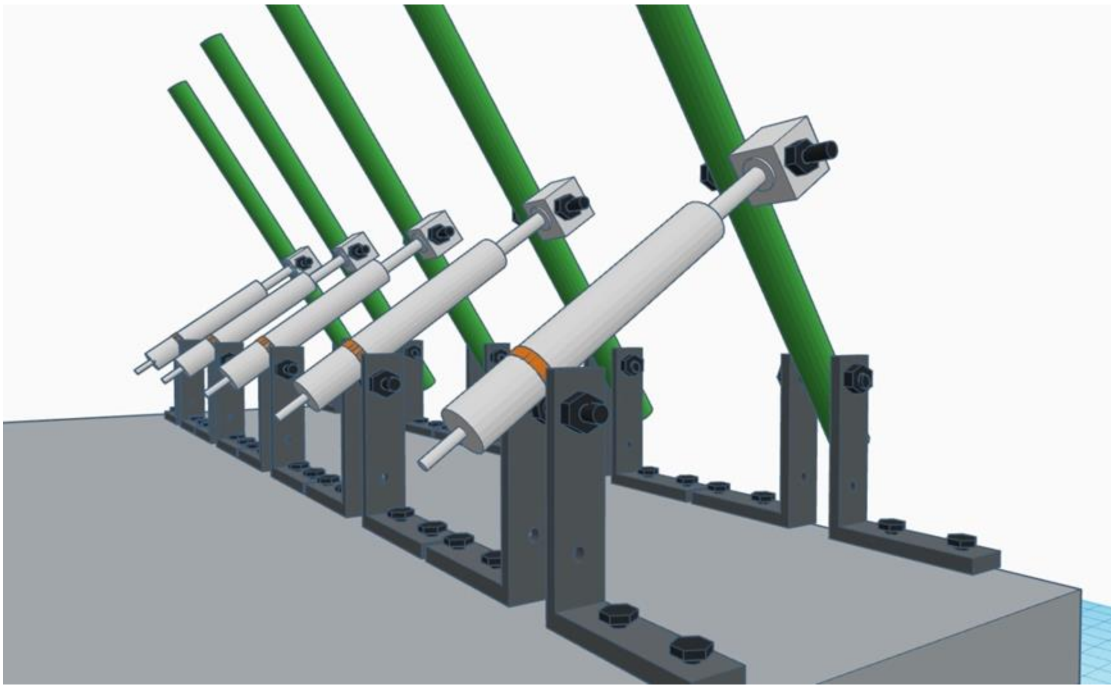

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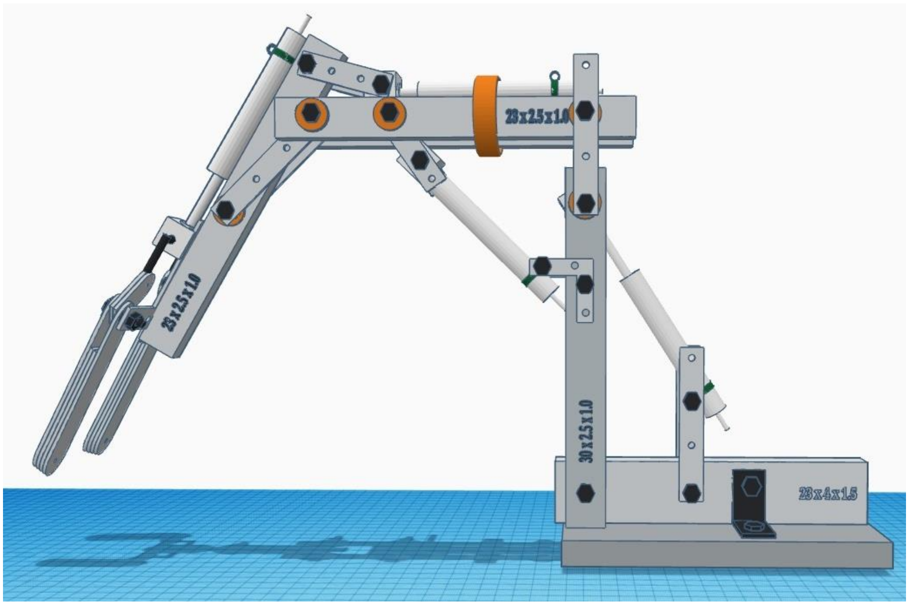

Figure 54

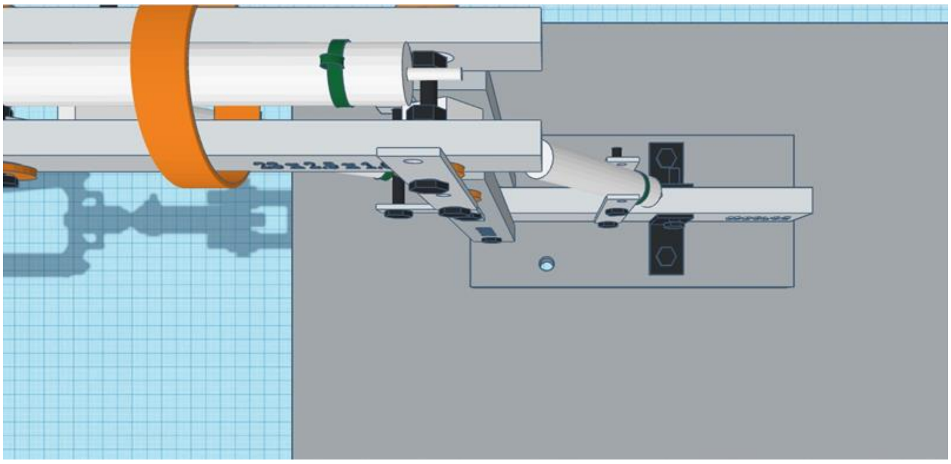

Figure 55

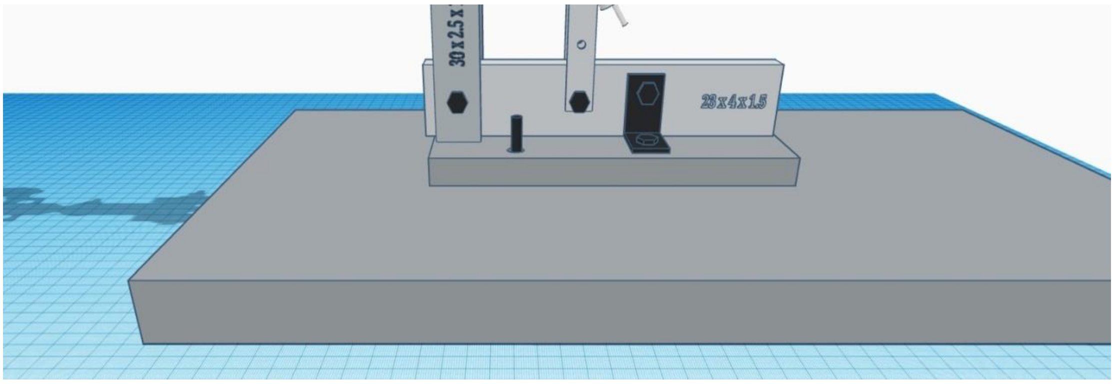

Figure 56

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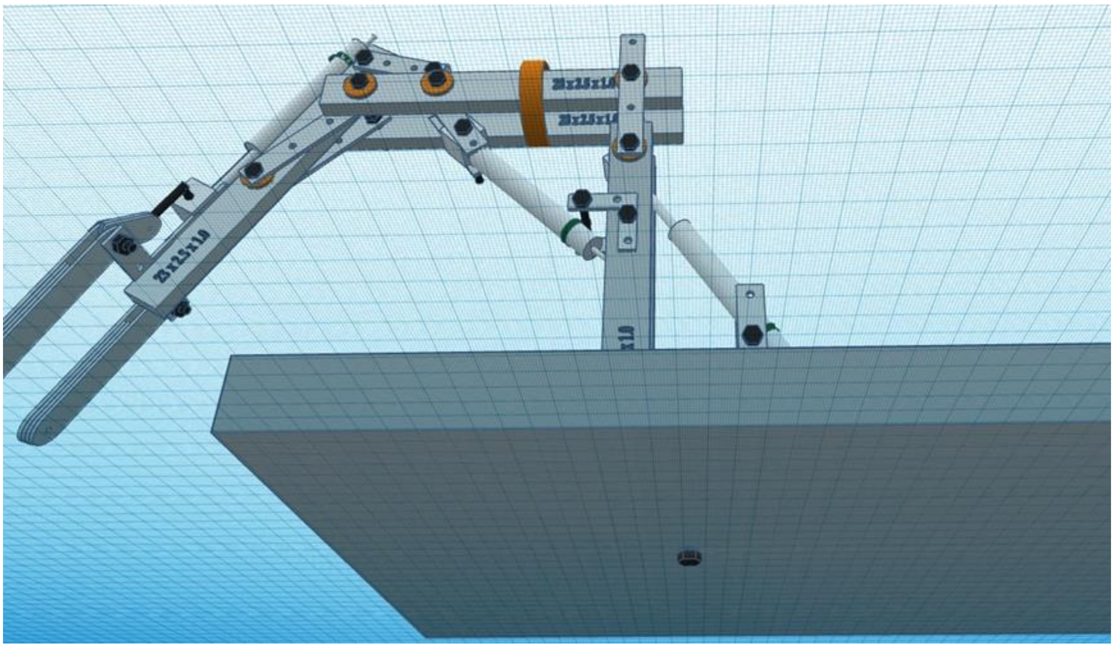

Figure 57

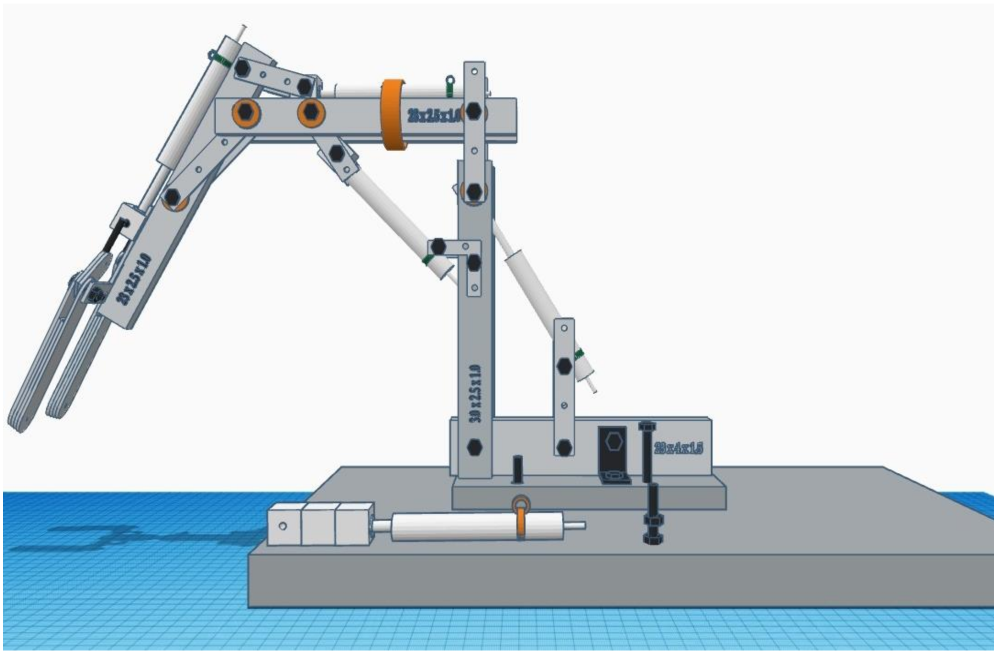

Figure 58

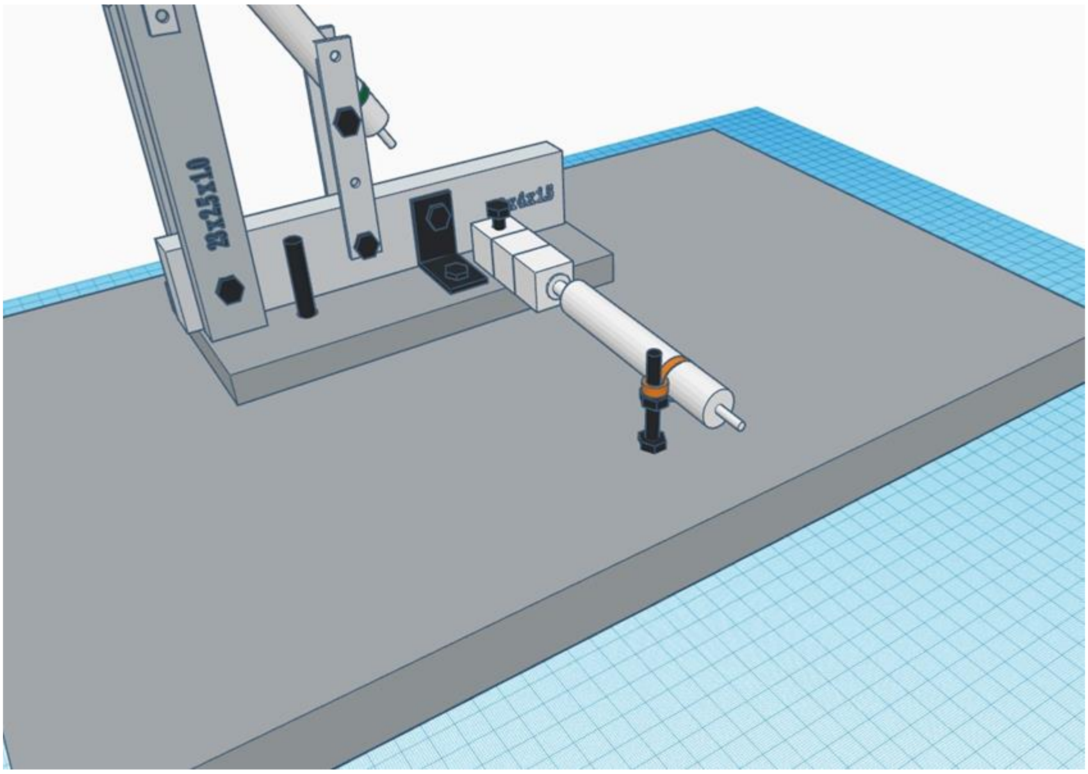

Figure 59

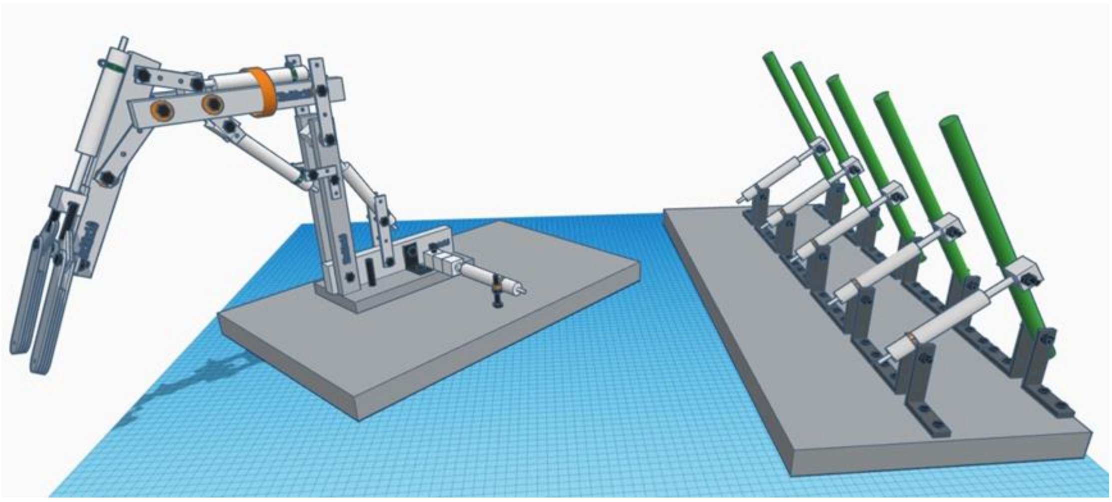

Figure 60

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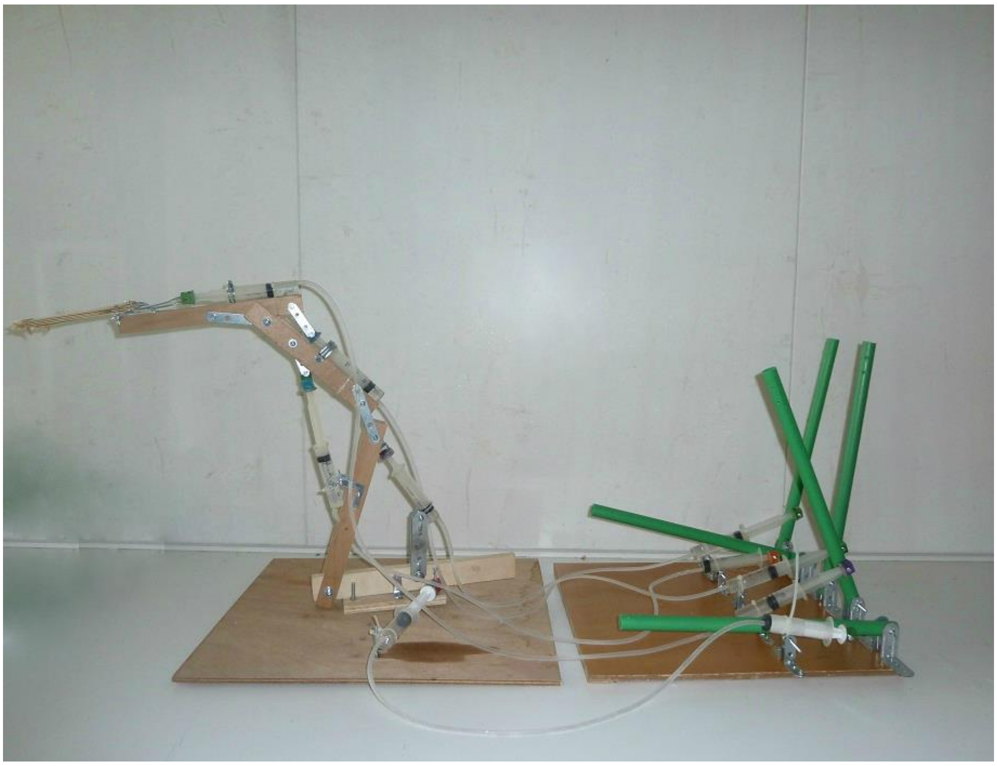

Figure 61

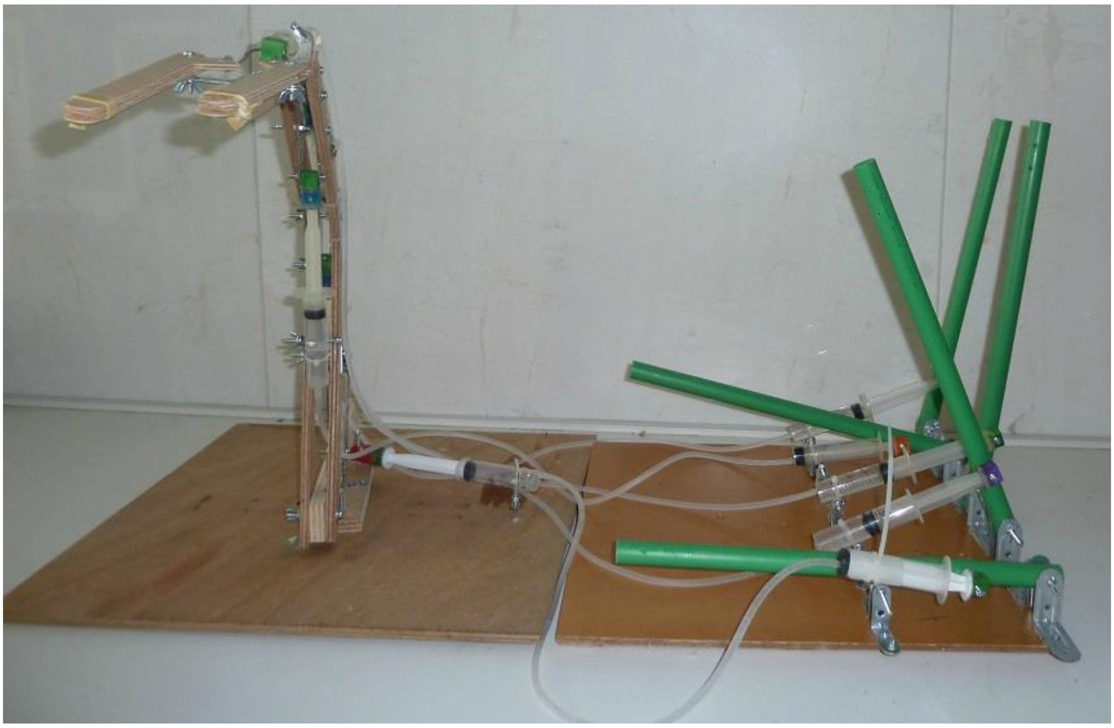

Figure 62

Science Careers and Your Future[1]

Pascal's Law states that the "Pressure applied to any part of a confined fluid transmits to every other part with no loss. The pressure acts with equal force on all equal areas of the confining walls and perpendicular to the walls. This is the basic principle for any hydraulic system."

Earlier, weights were lifted using pulleys, levers, block and tackles, etc. Movements for a ship’s rudder or steering a vehicle where achieved by mechanical linkages like cams, levers, couplings, and gears which made the system complicated. These manual or mechanical methods of operation had several limitations. They also involved huge man power and long working hours for a particular job. As the population and technology increased exponentially, the demand for quicker and easier to operate equipment increased. To cater to this need, hydraulic machines were introduced.

A simple hydraulic system consists of hydraulic fluid, pistons or rams, cylinders, accumulator or oil reservoir, a complete working mechanism, and safety devices. These systems are capable of remotely controlling a wide variety of equipment by transmitting force, carried by the hydraulic fluid, in a confined medium. Modern developments in hydraulics have involved many fields in engineering and transportation. These systems transfer high forces rapidly and accurately even in small pipes of light weight, small size, any shape, and over a long distance. These systems play a vital role from small car's steering to supersonic aircraft’s maneuvering devices. More powerful and accurate systems are also used in maneuvering huge ships.

There are several other areas where hydraulics is applied. They are:

i. Automobile garage
ii. Petrol pumps
iii. Measuring weights of heavy-lift trucks
iv. Hydraulic cranes
v. Automobile steering gears
vi. Automobile brake, (disc brakes)
vii. Ship's steering gear
viii. Robotics
ix. Aircraft's rudder and other maneuvering systems
x. Industries and power plants

[1] http://www.brighthubengineering.com/hydraulics-civil-engineering/43171-what-are-the-basic-principles-of-hydraulics/

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xi. Servo mechanisms and control systems etc.

For Events (tips on setting up and running the challenge in an event setting)

If this challenge takes place in a science festival or a science museum as a:

i) **Mini-Workshop (90 minutes)**

As this is a workshop taking place in a festival or in a museum time is relatively limited.

- Skip the Preparatory Activity Strong Paper Table. Discuss with the participants the concepts of engineering and technology. Focus on the Engineering Design Process only as it consists of the core of the whole project.
- From Activity 1 state the problem and focus on the constraints and the criteria that must be met. Have them pose questions concerning the problem.
- Urge the participants to suggest the physical principles that underlie the problem. Skip the experiments proposed in Activity 3 that concern the scientific principles that underlie the engineering problem. Discuss the scientific principles that will be used.
- Review the other activities in terms of content and time, focusing especially on how to respond to questions that might come up.
- To avoid spending time teaching each person how to make a hydraulic arm, make samples that illustrate the process.
- Prepare many copies of the instructions as well as enough materials for 4-5 parallel sessions. Establish a testing zone for the testing/ presenting the final designs.
- Skip Activity 6-Present Final Solution.

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References

[1]. Henry Samueli School of Engineering and Applied Science, (2017). What engineers do. UCLA engineering. Available at: http://engineering.ucla.edu/descriptions-of-majors-offered/

[2]. College Factual. (2017). Engineering Overview. Available at: http://www.collegefactual.com/majors/engineering/, http://www.umich.edu/~ptclab/