[Rube Goldberg]

[Preliminary Report]

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2018 - Summer

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1 BACKGROUND

1.1 Introduction

The major aim of this project is to create a Rube Goldberg machine that will be used to water a plant so that it starts to appear as if it is really growing. In this design, the major focus will be on applying the various theoretical lessons learned in various engineering courses into reality. When we are through with the project, it will be of great significance to the sponsor and other stakeholders since it will be used to teach future students various engineering aspects and also be used as a form of brainstorming and leisure project. The team will make sure that the final design is perfect and thus satisfy the needs of the clients, However, the team will conduct a lot of research and exchange ideas amongst themselves to make sure that the functioning of the design is successful. In order to ensure that the team addresses the crucial aspects in selecting the most appropriate design, the team will make use of Pugh chart and decision matrix. The customer needs are the major points which must be considered to ensure success.

1.2 Project Description

According to Wonderopolis, a Rube Goldberg Machine is a device or apparatus that makes use of a chain of reactions to accomplish a very simple task in a manner which is indirect and complicated [1]. The team is required to create a Rube Goldberg machine that will have a number of complicated steps such that in the end, In order to accomplish the goal, the steps involved should be complicated. In this regard, there is need to use gears, fake hamster, hydrolysis, magnets, and sensor.

1.3 Original System

Our Rube Gold Berg machine started from the scratch with stand-alone ideas with no original system. In this regard, the team will embark on building an original device which has never been built before.

2 REQUIREMENTS

The team is required to liaise with the client so that they are able to know the actual requirements that will be incorporated in the final design taking into consideration the fact that the main aim of the project is to ensure that the last step of the Rube Goldberg machine pours water to a plant. Before the end of the project, the team wishes to accomplish a number of requirements to ensure that they succeed. First, there are customer requirements and this will be obtained directly from the clients since they are the ones who are going to interact with the device for a long period of time. Customer requirements will be helpful in figuring out the Engineering requirements. Since the engineering requirements are specific and measurable, the future analysis of the various designs will be made easy.

2.1 Customer Requirements (CRs)

Customer requirements are the various kind of requests which are given by the clients and the users regarding how the Rube Goldberg machine is supposed to be designed. The clients and the users are the major individuals who interact with the device and therefore they know its strong and weak points. The experience is very crucial since the clients and users may have views on the areas which need emphasis, the ones to be improved and which to eliminate completely. However, some of the customer requirements which will be included in the project are as discussed below. First, the design should entail 20 to 75 steps whereby a step is regarded as a time when the transfer of energy happens. The duration of the process should be less than 2 minutes. However, the speed of the steps should be normal such that the human eyes are able to capture every action. The steps also should be resettable. In addition, the device should be surprising, unexpected and entertaining to the audience. A prototype that is working should be presented. It should not be loud and no use of live animals. The total size should be 300cm3 i.e. 10ft by a 10ft grid. Lastly, there should be an inclusion of engineering equations such as fatigue problem and a factor of safety.

2.2 Engineering Requirements (ERs)

The engineering requirements are regarded as specific and measurable and are very crucial in making work in later stages easier especially in analysis and discussion. From the customer requirements, the team formulated engineering requirements which were to be used in the Rube Goldberg machine design and are presented in the table below.

Engineering requirement	**Target values**
Number of steps	20 - 75
Process duration	Less than 2 minutes
Size	10 x 10 ft
Speed	10cm/sec
Sound	No sound
Reset time	5 minutes

2.4 House of Quality (HoQ)

The team will make use of the House of Quality so as to determine the most significant engineering requirements for the project. The gadgets and equipment used in the making of the Rube Goldberg machine will be analyzed with respect to a variety of parameters. However, the most appropriate plan that the tea will settle on will be determined. However, the team will be required to remember all the requirements discussed. In this case, the customer requirements are listed on the left and are weighted depending on their importance on a scale of 1 to 5. However, 1 is the least important whereas 5 is the most important. See Appendix A for House of Quality.

3 EXISTING DESIGNS

A variety of competitions have been carried out regarding the Rube Goldberg Machine and as a result, the team conducted a research on them. It was no doubt that the team was supposed to conduct thorough research from a variety of sources such as the internet and interviewing users. The major emphasis was on designs which met the proposed customer requirements. In addition, the focus was on designs that had components which could be incorporated into the design at hand so as to satisfy the user's needs. The existing designs are as follows.

3.1 Design Research

Over the years there has been designing of Rube Goldberg Machines and there are changes which are incorporated every time due to technological innovations which are made in engineering aspects and also to meet the upcoming customer requirements. This has been made possible as a result of growth and development of technological advancement. In this regard, the team embarked on conducting an online research by use of the Google search engine and watching YouTube videos on the Rube Goldberg Machines which have ever been developed. The team was lucky to find a number of already existing designs related to the project and they are as discussed below.

3.2 System Level

Existing Design #1: Northern Arizona University 2018: Pouring a bowl of cereal

This design was second in the 2018 USA competitions and it was comprised of 38 steps as follows. Each sentence represents each step. Turning on the alarm clock. The arm of the clock sends the ball down the track and tube. The ball turns to switch "off". A metal ball is released from an electromagnet. The ball goes down the track, landing on a mouse trap. The mousetrap pulls the peg from under shoe. The shoe swings and kicks stopper. A fishing pole reels back. A ball's gate is pulled from its slot. The ball tumbles down spine track. It lands in a cup, pulling out the blockade. The soup can roll through cup tower, releasing weight. The weight pulls stopper from ball column. Balls release from the column, dropping into a cup. The cup falls, pulling open curtains, and landing on a long lever. The long lever triggers driving gear. Driving gear turns pinion, in turn moving the rack to the right. The top piece of wind-up toy pulls up the bottom piece. The bottom-half of wind-up toy rotates lever clockwise. A lever rotates fishing pole counterclockwise. A "Gate" lifts, releasing the first golf ball down its track. The golf ball falls into a mini cereal box, tilting the top track clockwise. The second golf ball rolls down the track and tube. The golf ball knocks out the wheel's peg. The wheel spins, dumping cereal into a dispenser as it does so, and ultimately pulls up on the box door's latch. The collapsing door falls, releasing a ball inside. The ball rolls down the track, bounces out of the box, hits the target, and bounces back in. the whale teeters tips. Cadillac Ranch "dominoes" fall. A hinge/latch is released. Malt milkshake cup falls. A nail is pulled from spoon launcher. The spoon launches into a bowl. The weight of spoon starts cereal pouring and start a DC motor that is attached to the handle of the cereal dispenser. Cereal exits dispenser and slides down a chute. Once 30 grams of cereal reaches the bowl, the DC motor turns off, and the stepper motor and its attached arm spin 180 degrees. A peg under the milk lever is swiped away by the stepper motor arm, tipping lever. Finally, milk pours into the funnel, through tubes, and into the cereal bowl [1].

Existing Design #2: Purdue 2018: Pouring a bowl of cereal

The machine design is focused on the one which pours a bowl of cereal and is comprised of three separate vignettes which were each rotated into view when the previous steps were complete. In the first vignette, a jug which is placed on a board triggered the operation of a blending machine which in turn triggered the plucking of wires of a guitar. Then the ball started rolling through a variety of steps which involved falling though hollows and being thrown to targets by use of springs. In the second vignette, the fan rotates thus blowing the ball which flows through a variety of stages and at the same time dropping downwards. There are a variety of gears and hinges which facilitate opening and movement of some

equipment. The ball eventually drops to a jar which turns and starts pouring water which in turn makes a turbine to rotate. In the third vignette, it is comprised the most innovative final step whereby a bowl of cereal was poured. In this case, there was a primitive hydraulic arm made of wood and syringes, which lifted and turned a Cheerios box [2].

Existing Design #3: Purdue 2018: put a stamp on an envelope

The design of the Rube Goldberg in the 2017-year competition required that students make a machine that uses the most complex process to put a stamp on an envelope, screw in a light bulb and make a cup of coffee in 20 steps or more [3].

3.3 Functional Decomposition

In this project, the major aim is to create a Rube Goldberg machine that will be used to water a plant so that it starts to appear as if it is really growing. The functional decomposition of the team is to design a device that meets all the requirements given by the client. However, this section contains a black box model and functional model of the device, to be achieved in the project. When both models are analyzed and utilized, there is the identification of the focus of the device for further emphasis in the design process.

Black Box Model

In the black box model, the major focus is on the various mechanisms and operations of the device that eventually leads to the pouring of water onto a growing plant. In order to represent all these processes, a box will be used as a simulation of the entire machine whereby inputs on the machine will be presented on one side whereas outputs are presented on the other side. In the black box model, the inputs which are being considered include the various forces which are incorporated for energy production, the types of materials and gadgets which have been used and the way they are linked to each other to ensure that there is a smooth flow of the entire process. However, it should be noted that there is a combination of mechanical and electronic elements which lead to the production of various forms of energy including mechanical and electrical energy. There is also the potential energy which is presented by the water which is stored ready for releasing or some other sort of material like the sand which is stored so that once it is released, it will trigger another action. For instance, at the start of the steps, there is the input of human energy whereby the ball must be set rolling by the hitting action. In other parts, the rotating gears and wheels lead to the production of kinetic energy which triggers some actions. For instance, the rotating wheel with a hook leads to knocking down of a bucket full of water. However, the major form of outputs which are manifested in this design includes the production of a various form of sounds as result of rolling and dropping of the ball on various paths, lighting and the pouring of water to flow along a certain tunnel and eventually onto the growing plant.

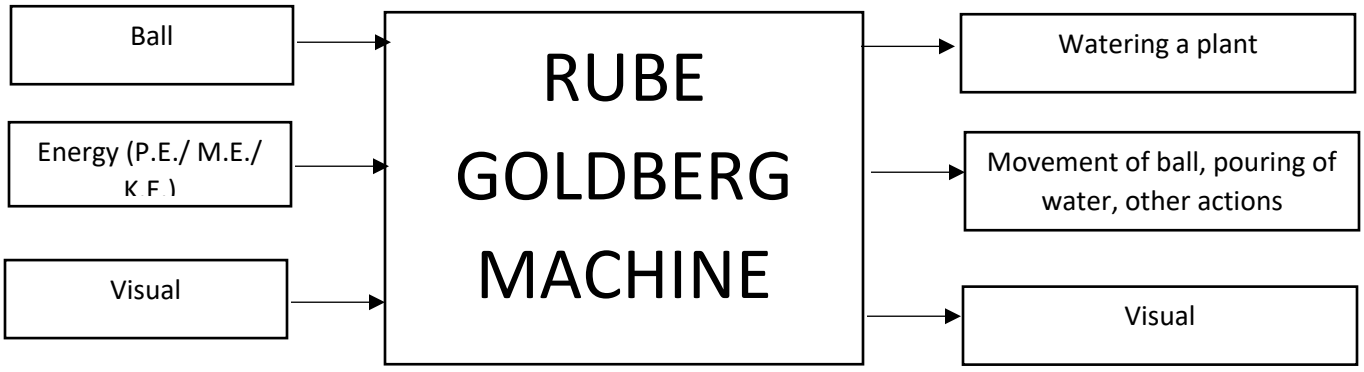


Figure 1: Black Box model

Functional Model/Work-Process Diagram/Hierarchical Task Analysis

The functional model gives an explanation of the process which has already been described in the black box model in a stepwise manner. as evidenced by the functional model, the Rube Goldberg machine is comprised of numerous operations which made use of human energy, electrical, potential and even mechanical energy. A number of mechanisms which have been well organized have been integrated into a unique and amazing set up so as to push, hit, drop and even throw the ball to the required target. For instance, in areas where there is mechanical energy, it is converted into kinetic energy once the ball starts rolling so as to hit a target or to move to a particular destination. The diagram of the functional model used is in Appendix B.

3.4 Subsystem Level

The subsystem levels of the already existing designs addressing the requirements relevant to our project are as discussed below.

Subsystem #1: Levers

Levers are very crucial in this project as they will be used to make work easier by lifting heavy weights with the lowest amount of effort.

Existing Design #1: Class 1 lever

Class 1 lever has the fulcrum which is positioned between the effort and the load. The load moves in the opposite direction to the effort. This is crucial in our project as it will help to move heavy loads.

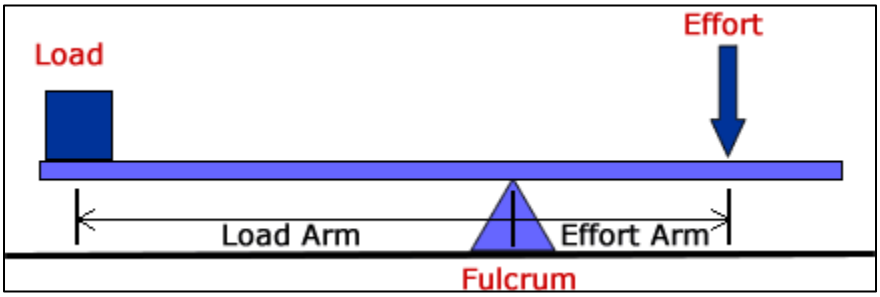


Figure 2: Class 1 lever

Existing Design #2: Class 2 lever

The load is between the effort and the fulcrum and the load moves in the same direction as the effort. This is crucial in our project as it will help to move heavy weights.

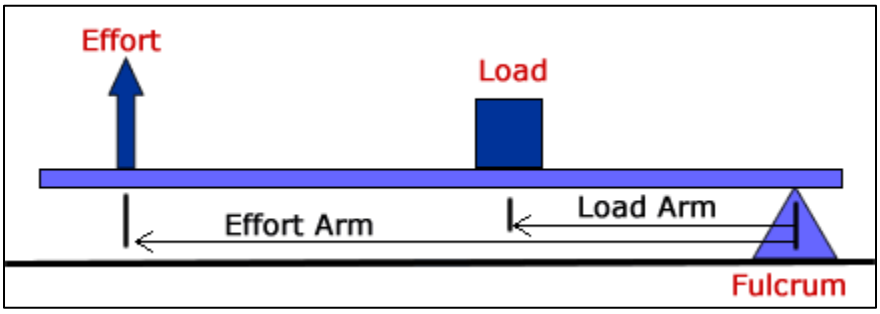


Figure 3: Class 1 lever

Existing Design #3: Class 3 lever

The effort is between the load and the fulcrum and the load and effort are in the same direction. This is crucial in our project as it will help to move heavy weights.

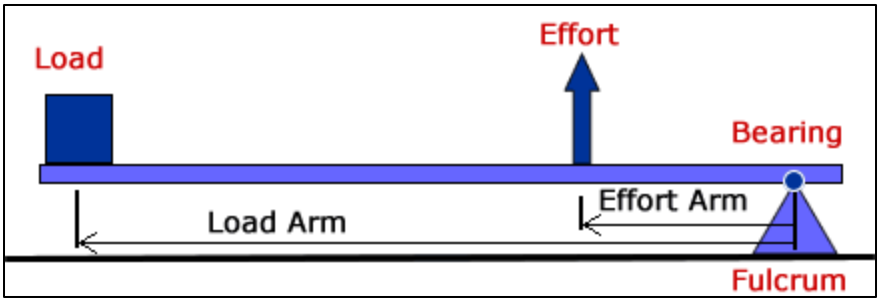


Figure 4: Class 1 lever

Subsystem #2: Hinges

Some of the hinges which have been used are made up of steel, aluminum and plastic. Hinges are of great significance to this project since they are used at every joint to facilitate movement.

Existing Design #1: Descriptive Title

In our project steel hinges are crucial since they are light in weight and strong. In addition, they are long lasting.

Figure 5: Steel Hinges

Existing Design #2: Aluminum hinges

Aluminum hinges crucial in our project since they are strong and light in weight. They are also rust resistant.

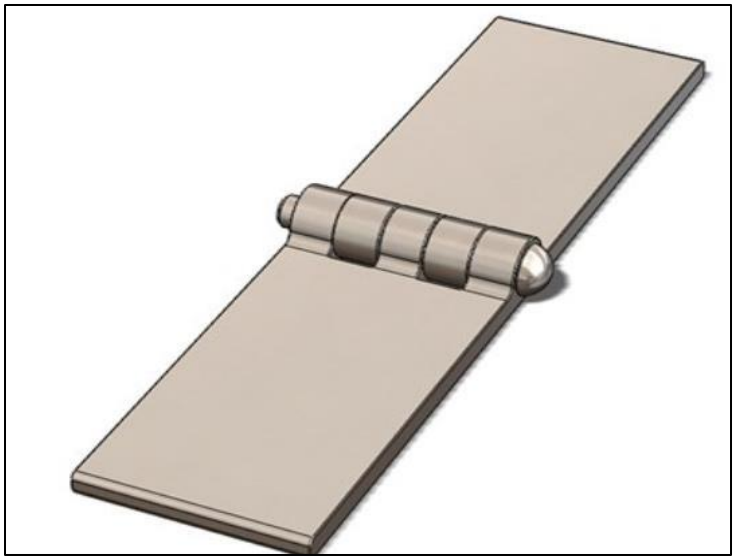


Figure 6: Aluminum Hinges

Existing Design #3: Plastic hinges

Plastic hinges are also crucial in our project since they are light in weight and easy to clean. However, they can be modified with ease through heat application and drilling holes.

Figure 7: Plastic Hinges

Subsystem #3: Gears

Gears are used to transmit forces and rotations from the shaft which is driving to the one being driven. They are crucial in our project as they will help in efficient movement of some components.

Existing Design #1: Spur gears

They are cylindrical gears with a tooth line which is parallel and straight to the shaft. These gears are crucial in our project since they are able to achieve high accuracy with easy production processes.

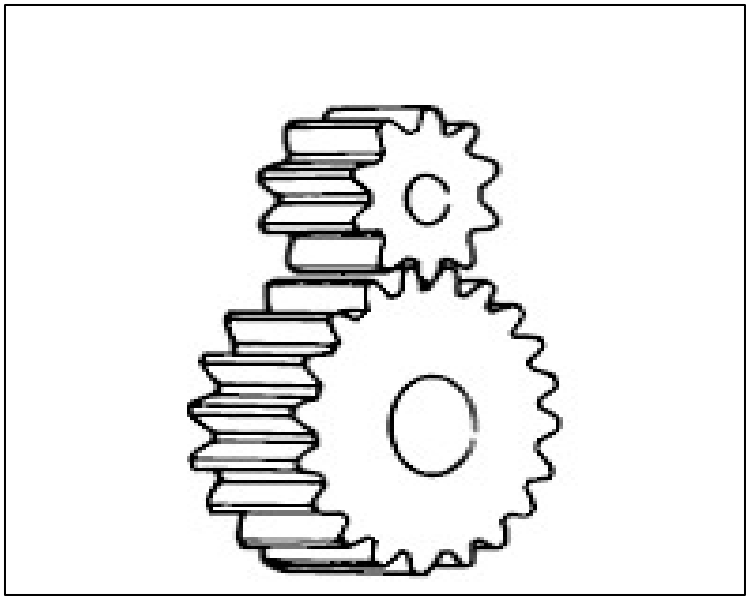


Figure 8: Spur gears

Existing Design #2: Helical gears

They are cylindrical gears which have winding tooth lines. They are suitable in our project since they are able to transmit higher loads at high speed and with superior quietness.

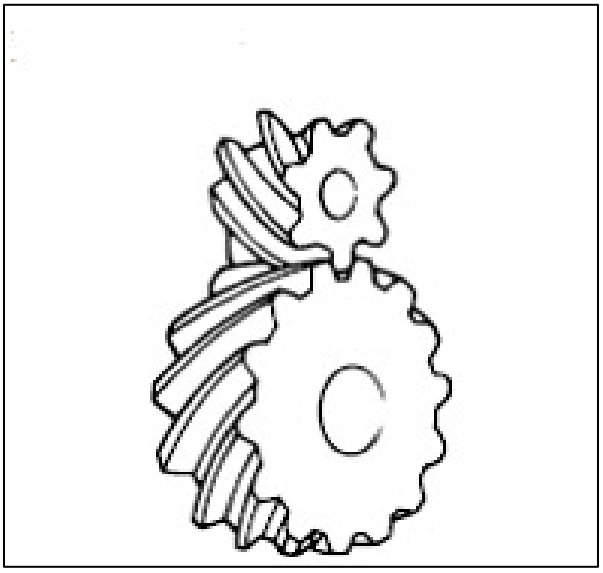


Figure 9: Helical gears

Existing Design #3: Gear rack

They are gears which are characterized by teeth of same size and shape which cut at equal distances along a flat surface. This gear is crucial in our project as it will enhance conversion of rotational motion into linear motion.

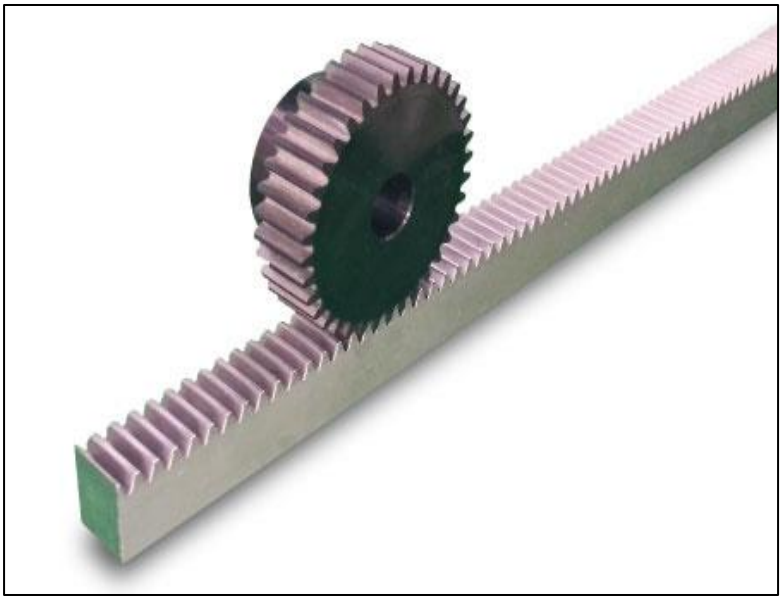


Figure 10: Gear rack

4 DESIGNS CONSIDERED

Before the start of the project the team brainstormed as many designs as possible but a lot of emphases was on the ones which met both the customer and engineering requirements. Some of the designs considered are as follows.

Design #1: Energy transfers

This design is showing various energy transfers in various stages. A fan on rotating produce wind which has energy used to roll a ball on a wooden platform. The ball drops into a box full of sand and its impact makes the hinged box to open its base hence releasing sand. The sand drops inside a basin placed on one end of a seesaw. This triggers rising of the other end of the seesaw and hence raising a fishing rod attached to it. The lower end of the fishing rod is attached to a bucket with water. The pulling action of the rod topples the bucket and water is poured along a plastic tunnel onto a growing plant.

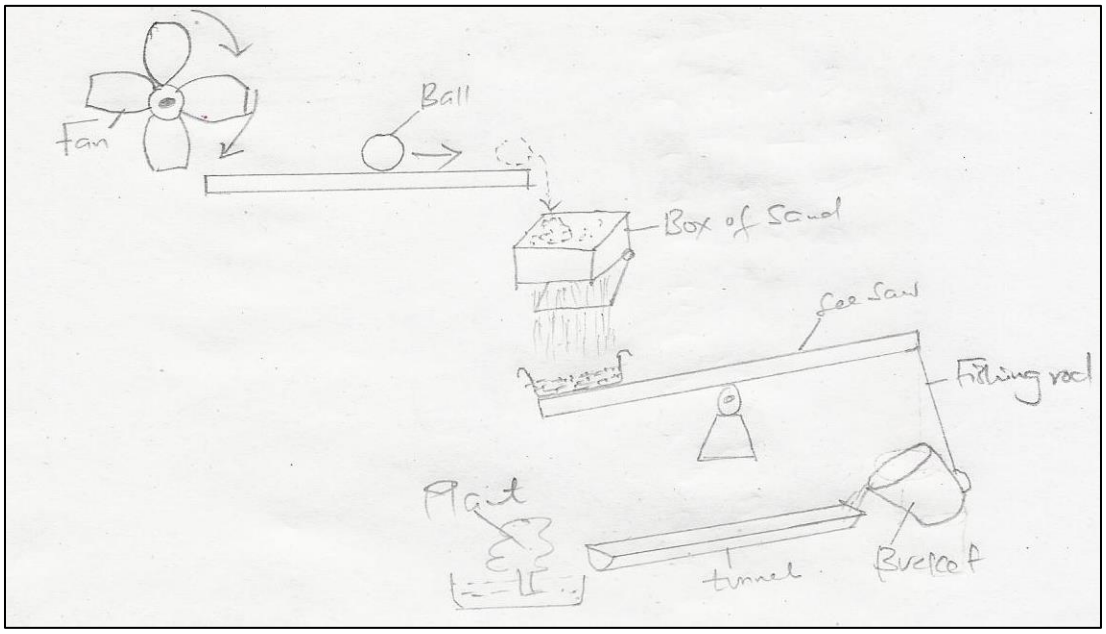


Figure 11: Energy transfers

Design #2: Various stages

In this design an arrow is shot at an inflated balloon such that on rupturing a ball is dropped and rolls along a wooden platform on one stage. In another stage the ball drops onto a switch which triggers rotating of a wheel with a hook in a clockwise direction. In another stage a bucket placed along the path of the book is knocked down and falls thus pouring water into a funnel connected to a pipe and leading to the plant to be watered.

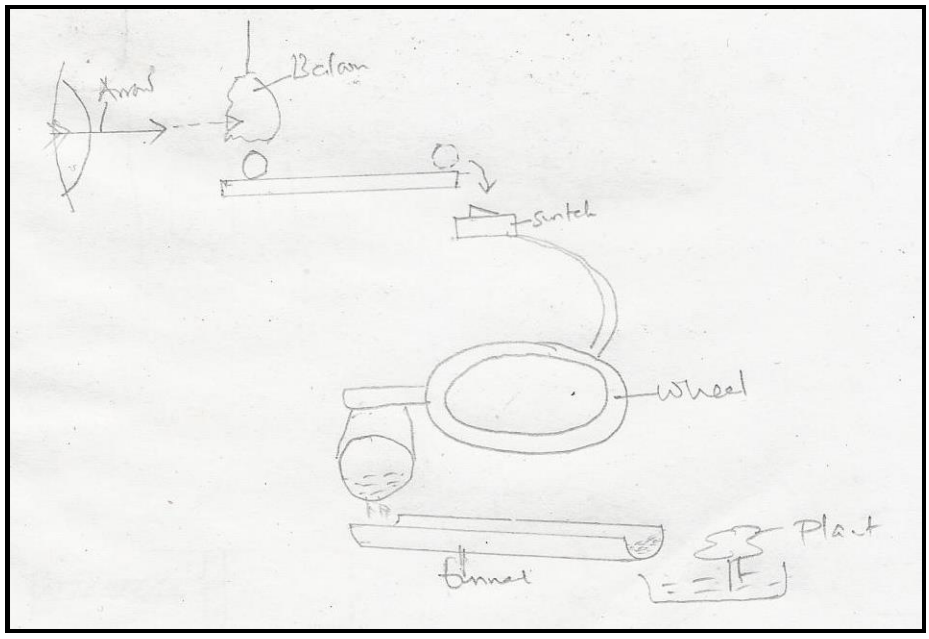


Figure 12: Various stages

Design #3: Action of a Spring

This is a design whereby the process starts with hitting of a ball with a ball using a wooden rod making t to roll along a wooden platform and dropping into a jar with a base with a spring. On hitting the spring, the ball hits one end of a seesaw balance which in turn leads to opening of a stopper which opens thus leading to water release held in a bucket. The water flows through a tunnel onto the plant being water.

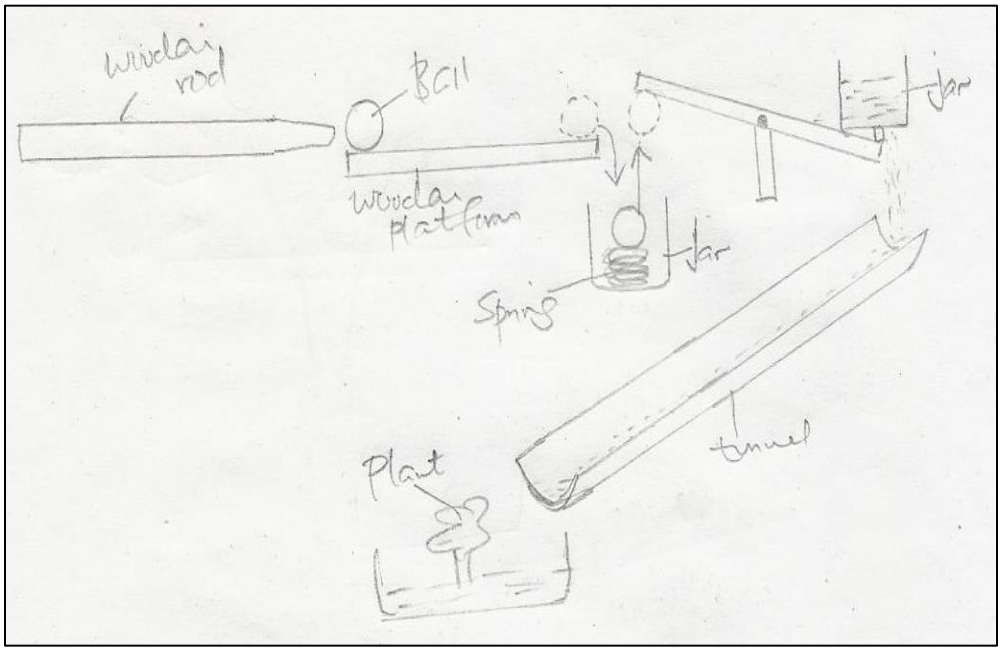


Figure 13: Action of a spring

Design #4: Pumping section

This section entails the pumping section whereby once the force is exerted on a bicycle pump the pressure exerted forces water to overflow in a jar attached and eventually flow along a pipe onto the plat to be watered.

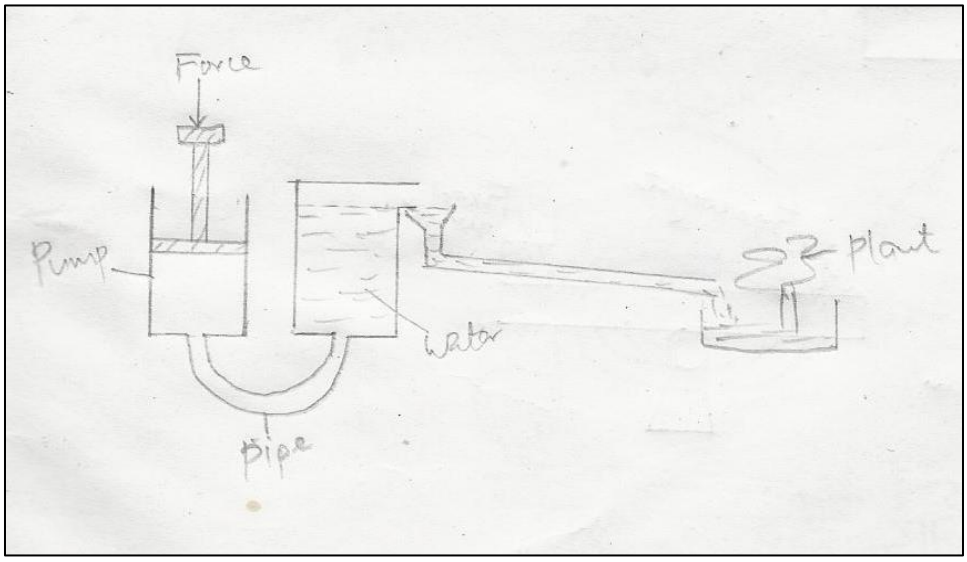


Figure 14: Pumping section

Design #5: Rotating bowl

This section is composed of a rotating bowl with water and the rotating is facilitated by a mortar. Due to the high rotating speed the centrifugal force makes the water to be thrown out of the bowl and it is collected in a surrounding large bowl which is then connected to a pipe onto the plant being watered.

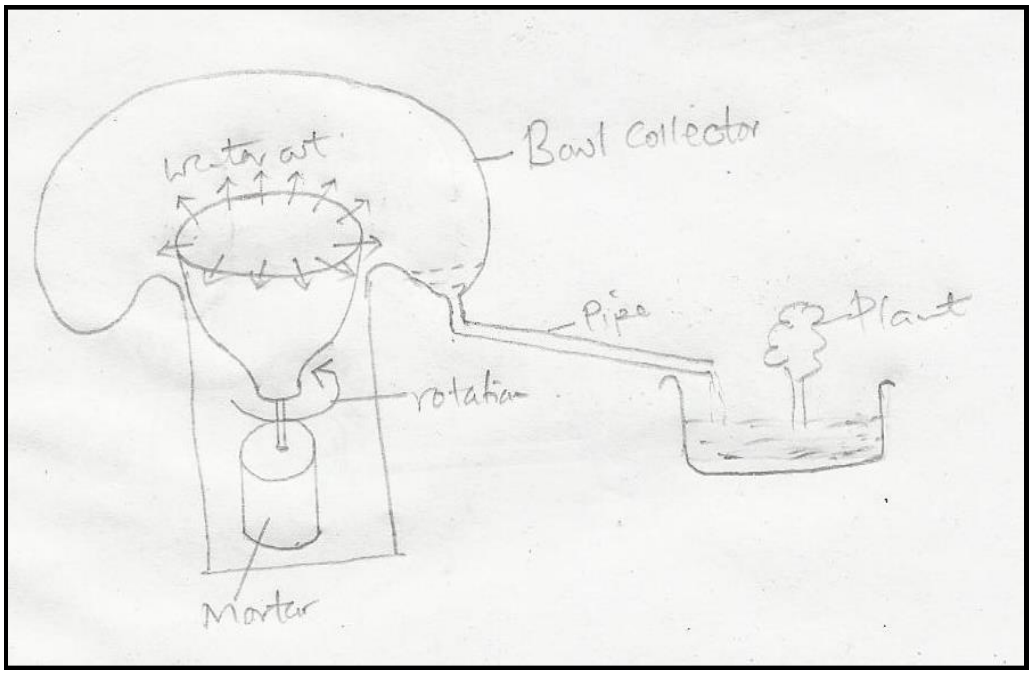


Figure 15: Rotating Bowl

5 DESIGN SELECTED – First Semester

In this section, the best design which meets the client's requirements is selected. Before settling on the final design the team must ensure that the design selected meets all the requirements by looking into all the components. The major requirements to be met include the customer needs and also come up with a design which is efficient and reliable. The team made use of a decision matrix and a Pugh chart to select the most appropriate design. Based on these criteria, design 10 had the highest score. The team selected design #3, which integrated a wide range of designs to meet proposed requirements including meeting the needs of the client, users, and making an improvement on the already existing designs. Design #3 gained a total score of 23 points thus making it emerge the best. As a result, a lot of focus was given to improve design #3. The Decision Matrix that was used is in the appendix C1. A Pugh Chart was used to show the criteria which were used by the team in analyzing the 21 concept designs which were brainstormed by the team. The team used design #12 as the DATUM. This means that the analysis was based on design #12 and hence designs which shared similarities with the DATUM were focused on. The reason for selecting the design #12 as the DATUM was because it met most of the requirements such as 20 to 75 steps; duration process of fewer than 2 minutes; normal speed; resettable; entertaining to the audience and have a total size of 10ft by 10ft. the Pugh chart reveals that the third design is very close to the engineering requirements which are presented by the clients. The Pugh chart used is in appendix C2.

REFERENCES

[1] https://wonderopolis.org/wonder/what-is-a-rube-goldberg-machine

[2] https://www.cefns.nau.edu/capstone/projects/ME/2018/RubeGoldberg/index.html
[2] https://www.youtube.com/watch?v=zPVH2admAuw
[3] 1]"Contest – Rube Goldberg", Rubegoldberg.com, 2017. [Online]. Available: https://www.rubegoldberg.com/contest/.

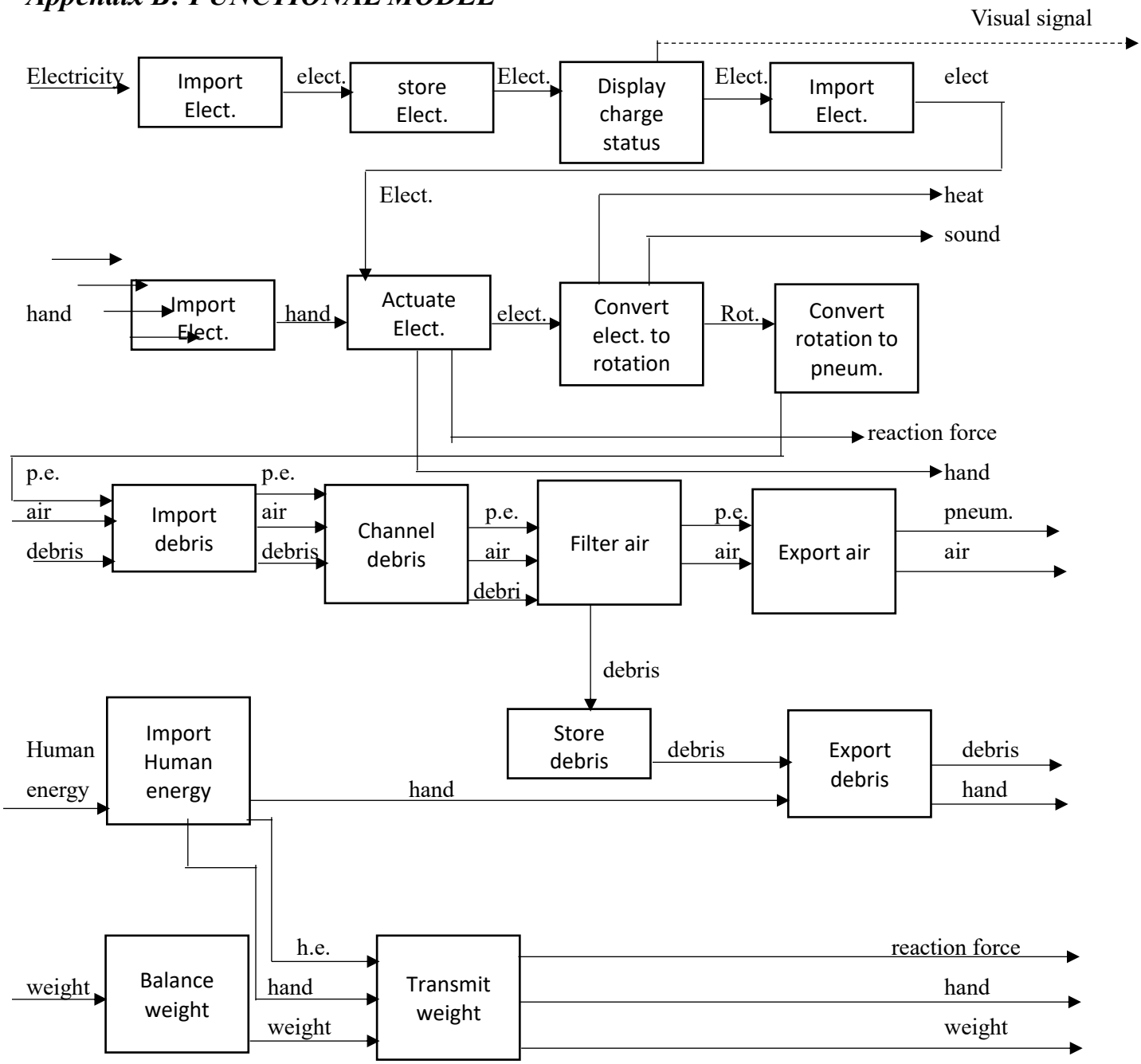
APPENDICES

Appendix A: HOUSE OF QUALITY

House of Quality								
Customer Requirement	**Weight**	**Engineering Requirement**	**Number of steps**	**Process duration (min)**	**Size (cubic feet)**	**Speed (m/s)**	**Sound (dc)**	**Reset time (min)**
Reliable	5		4	3	5	4	0	4
Durable	5		0	0	1	1	0	0
20 to 75 steps	5		5	4	1	3	1	1
Each process less than 2 minutes	4		5	5	0	5	0	4
Normal speed of the steps	3		4	4	0	5	0	2
Total size of 10ft by 10ft	3		1	0	5	0	0	0
Should be resettable	2							
Should be entertaining to the audience	2		0	0	0	2	0	0
Should not be loud	1		0	0	0	2	5	1
Absolute Technical Importance (ATI)			80	67	50	81	10	48
Relative Technical Importance (ATI)			27.8	15.6	13.1	3.2	18.6	4.5
Target ER values			<75	<2	<300	<10	< 0	<5
Tolerances of ERs			0	0	0	0	0	0
Testing Procedure (TP#)								

Strong relationship = 3; Weak relationship = 1; No relationship = 0

Appendix B: FUNCTIONAL MODEL



Appendix C: EXTRA DESIGNS

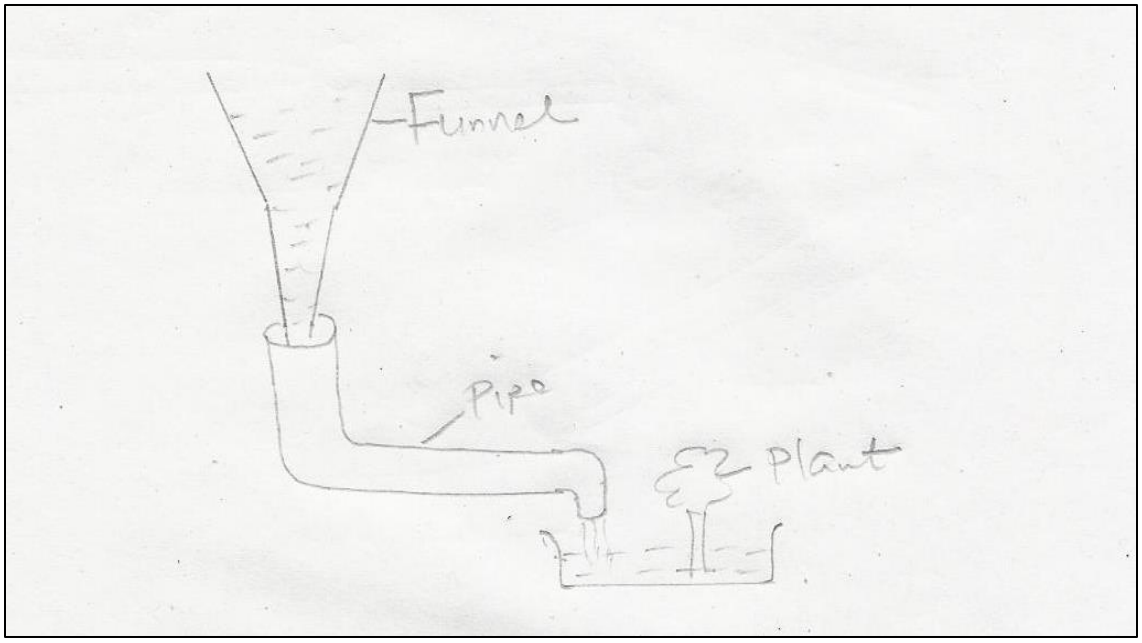


Figure 16: Design #6: Rotating bowl

The funnel for collecting water step: This is a water collection system which is comprised of a funnel. However, the funnel is attached to a small pipe which leads all the way to the plant to be watered.

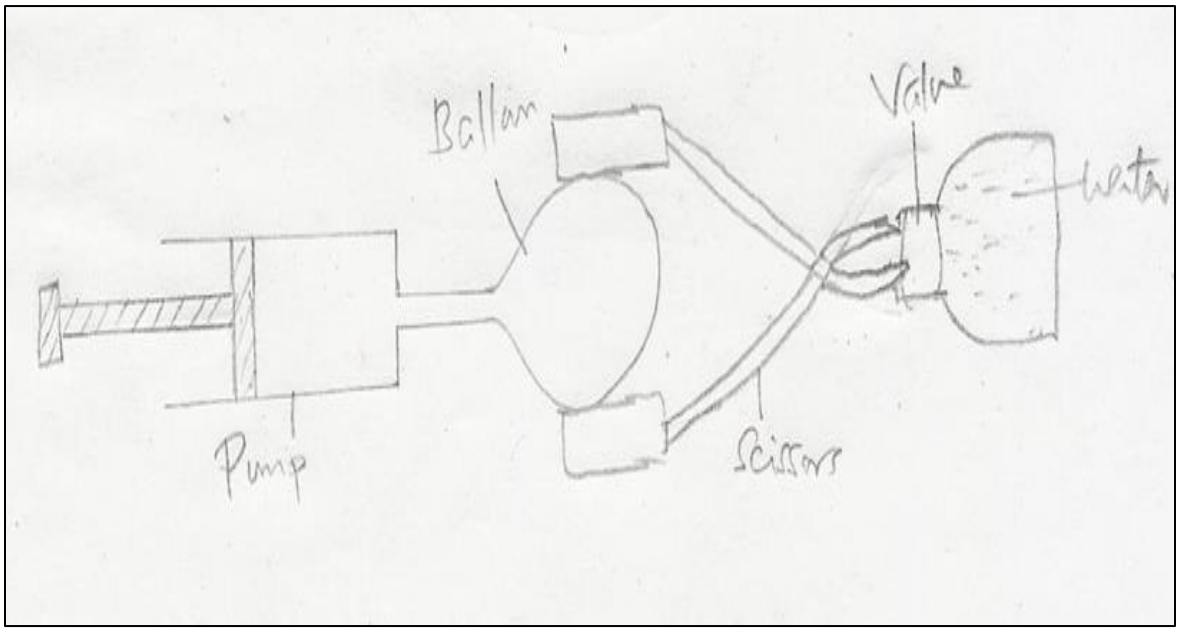


Figure 17: Design #7: Rotating bowl

Opening of a valve: in this step the pressing of a bicycle pump downwards leads to inflation of a balloon which in turn leads to opening up of scissor's edges. The edges are attached to an elastic valve.

When the scissors edges are opened the elastic valve opens leading to pouring of water.

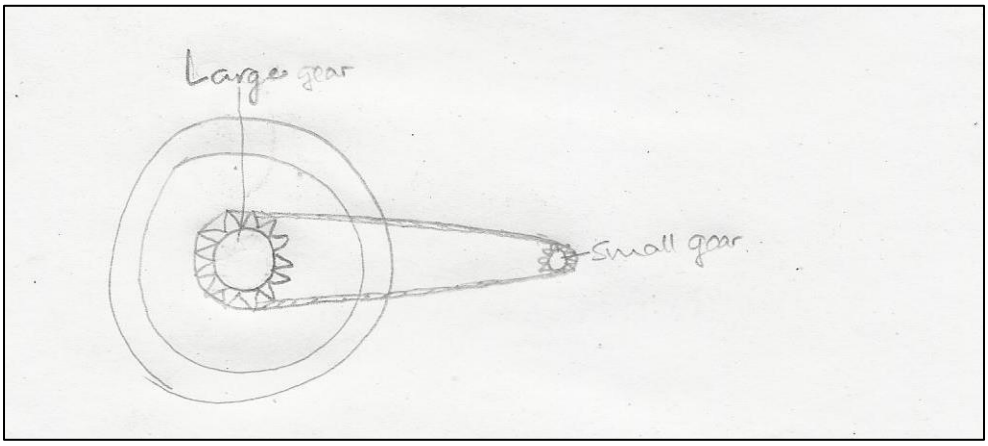


Figure 18: Design #8: Rotating wheel section.

In this part there is a large wheel which is rotated by use of a pair of gears which are connected using a chain.

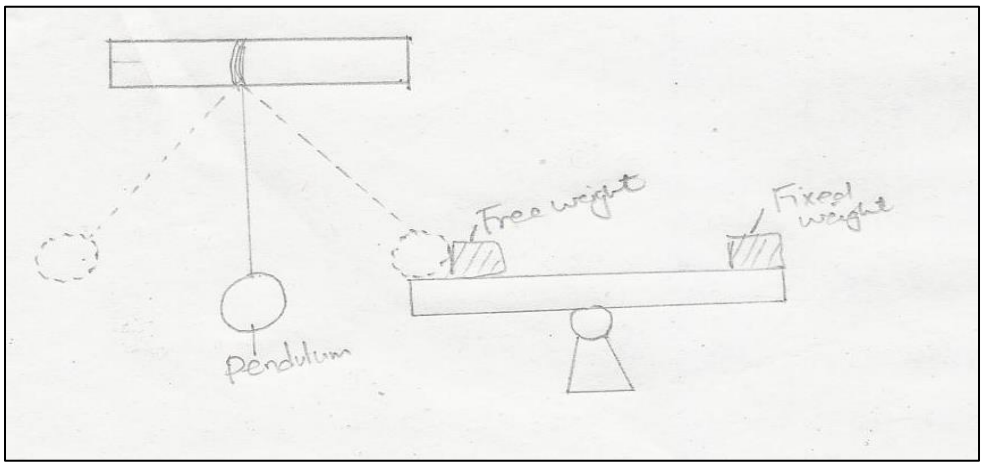


Figure 19: Design #9: The pendulum section

In this step a pendulum swings and in turn hits a free weight placed on a seesaw thus triggering another activity in another section.

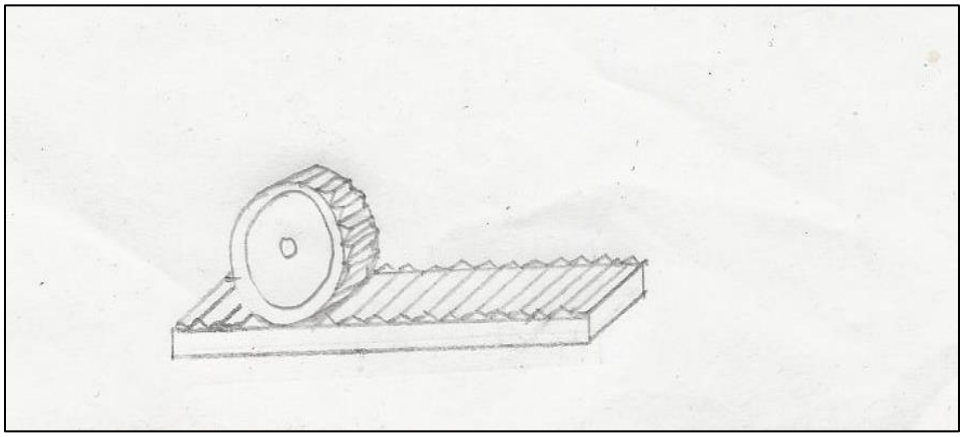


Figure 20: Design #10: Gear rack section:

In this part the gear racks are crucial since they convert rotational motion into linear motion. It is applicable where there is need to change the direction of movement.

Figure 21: Design #11

The candle burns a cotton string holding a book on one side. When the string snaps the book falls on a weighing machine and pulls the string through two pulleys which pours the water in the jar into the flower pot.

Figure 22: Design #12

Above the candle there is a bag holding balls. When the candle is lit it burns through the bag releasing the balls down the slope. The balls land on the left side of the weighing machine and the right side goes up. When the string attached to the weighing machine is plucked it pours water to put off the candle.

Figure 23: Design #13

A Rube Goldberg machine, which starts when the candle at the top left, is lit. The flame of the candle pushes the plate up forcing the ball to fall. The ball pushes down the cart, which falls on the weighing machine. Below the weighing machine rotates the gear which scores the red ball into the net.

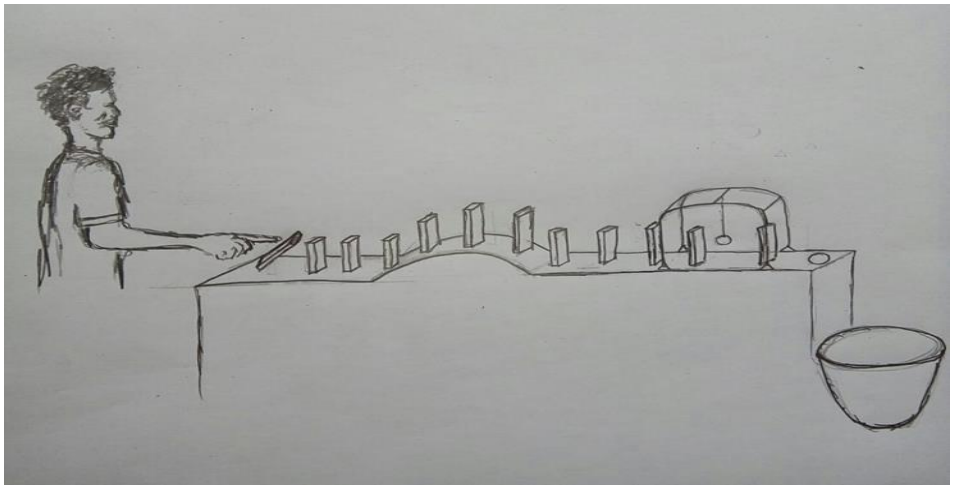


Figure 24: Design #14: A Rube Goldberg machine pushed by hand.

The hand pushes one bar, which fall on the next and forth until it pushes the pendulum, which scores the ball at the edge of the table to the bucket.

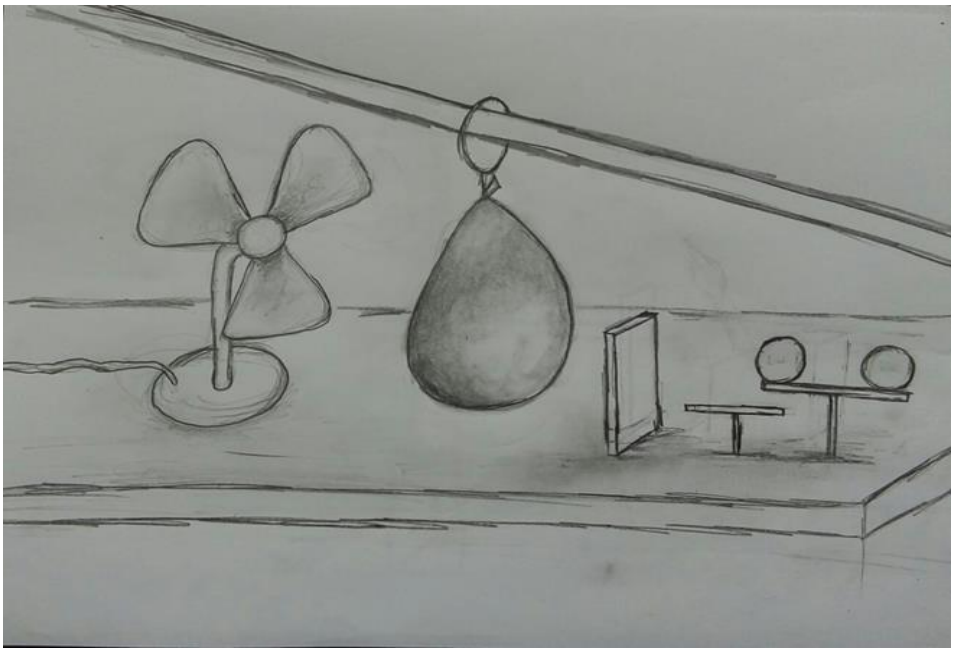


Figure 25: Design #15: A Rube Goldberg machine used to push two balls off the edge of a table.

When the fan is turned on, it blows the balloon, which pushes a metal bar. The bar falls on a balancing machine then tilts the second balancing machine sending the two balls off the edge of the table.

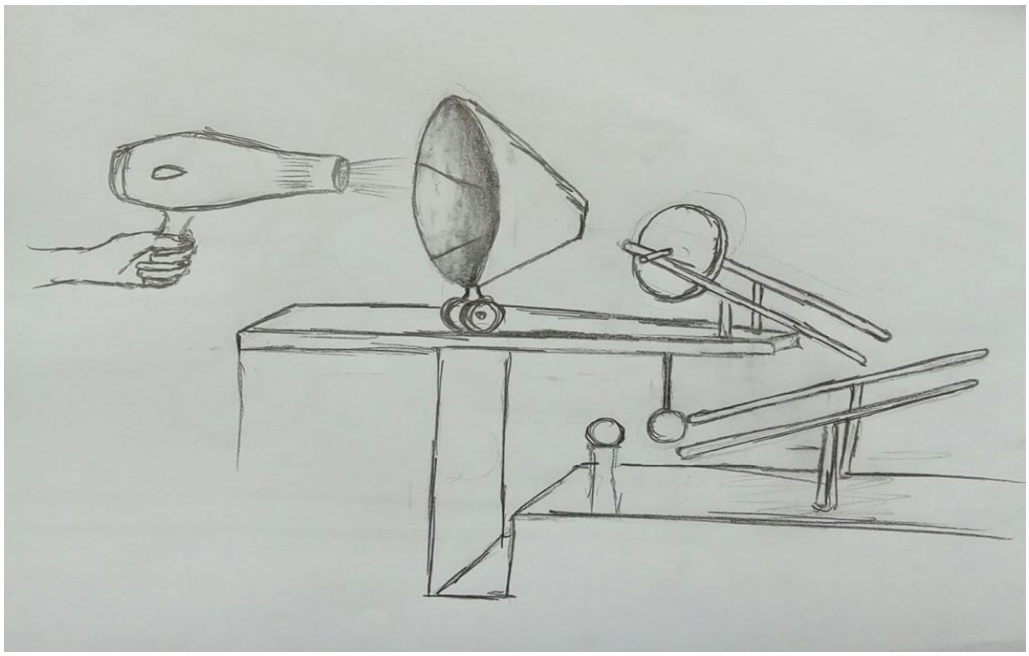


Figure 26: Design #16:

The hair dryer pushes the umbrella that pushes the wheel down at high speed. The wheel kicks the pendulum, which pushes the ball and causes it to fall.

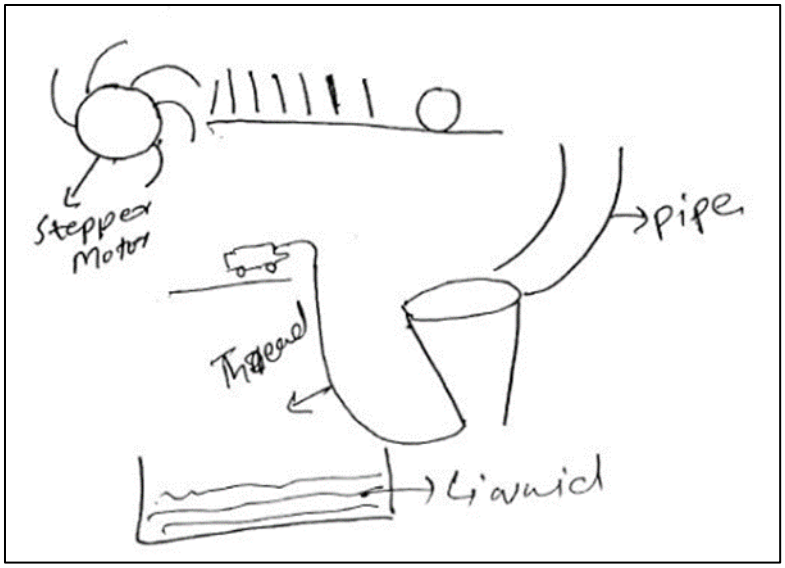


Figure 27: Design #17: Electric Motor ball hit Liquid

In this Rube machine, an electric stepper motor will turn on by electricity, as the motor will start, it will hit the first card, that card will drop down all other cards and last card will hit the ball. That ball will go into the pipe, and that pipe will pass the ball into nozzle, when the ball will go into nozzle, it will stop moving and increase the weight of nozzle which in turn move down, when nozzle move down, it will stretch the thread attach to the item place on shelve, and that item will fall down into the liquid present in the bowl. So the simple form of task is to put that item into the bowl. As it is showing in the following figure.

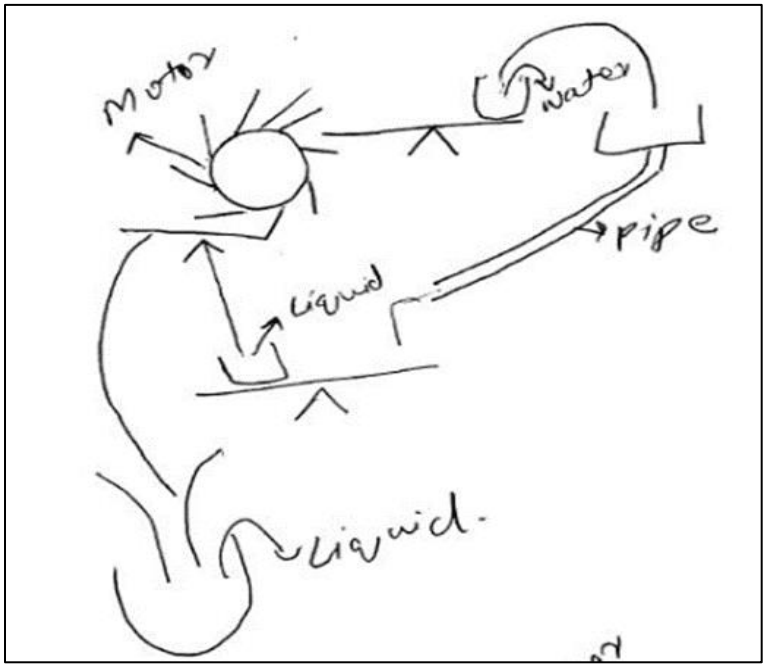


Figure 28: Design #18: Electric Motor based liquid mixing

In this design, an electric motor will connect with the seesaw in such a way that when the motor rotates, its fin hit one side of seesaw and then the other side which moves up have liquid in bowl, which splash up and went into the pipe, that liquid went down with high pressure and exaggerate the second seesaw and raise it up, liquid present in the second bowl also splash up and went down to the final bowl after hitting the top hurdle which save the electric motor from any splashes.

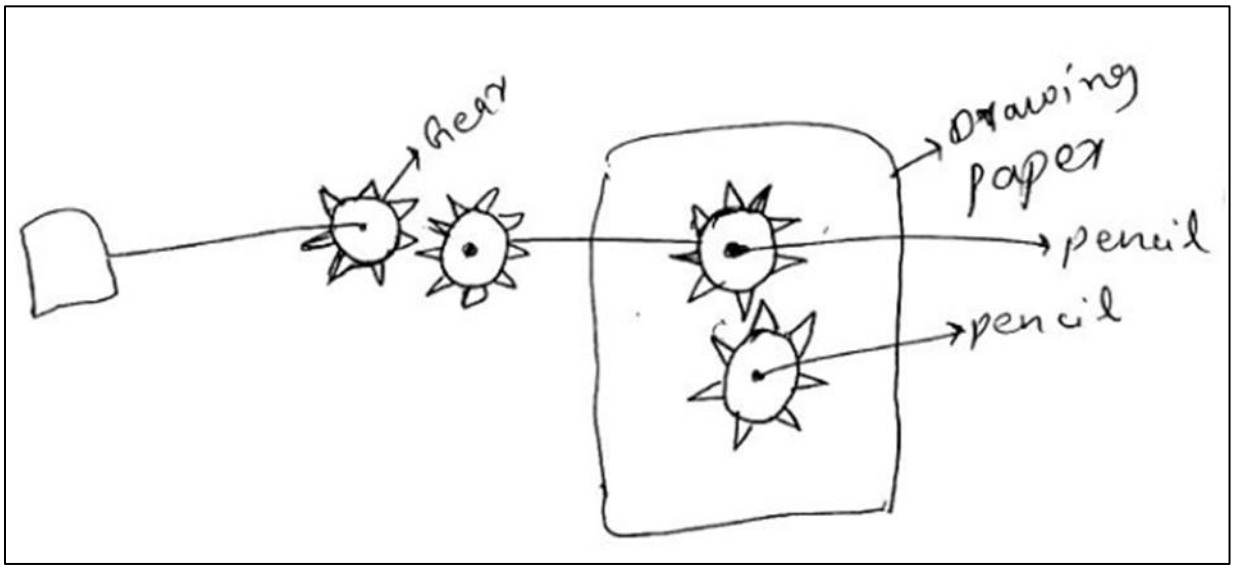


Figure 29: Design #19: Interlocking Gear system mechanical work

In this design, there is a handle which attaches with the first gear, and teeth first gears interlock with the second gear, when the first gear rotates, second gear also rotates because of interlocking system. Second gear attach with the rotating shaft, and that rotating shaft connects with the third gear, so when the rotating shaft will rotate, it will rotate the third gear and third gear interlocked with the fourth gear. Both third gear and fourth gear have pencils with them which rotates and draw a Spiro graph on the paper.

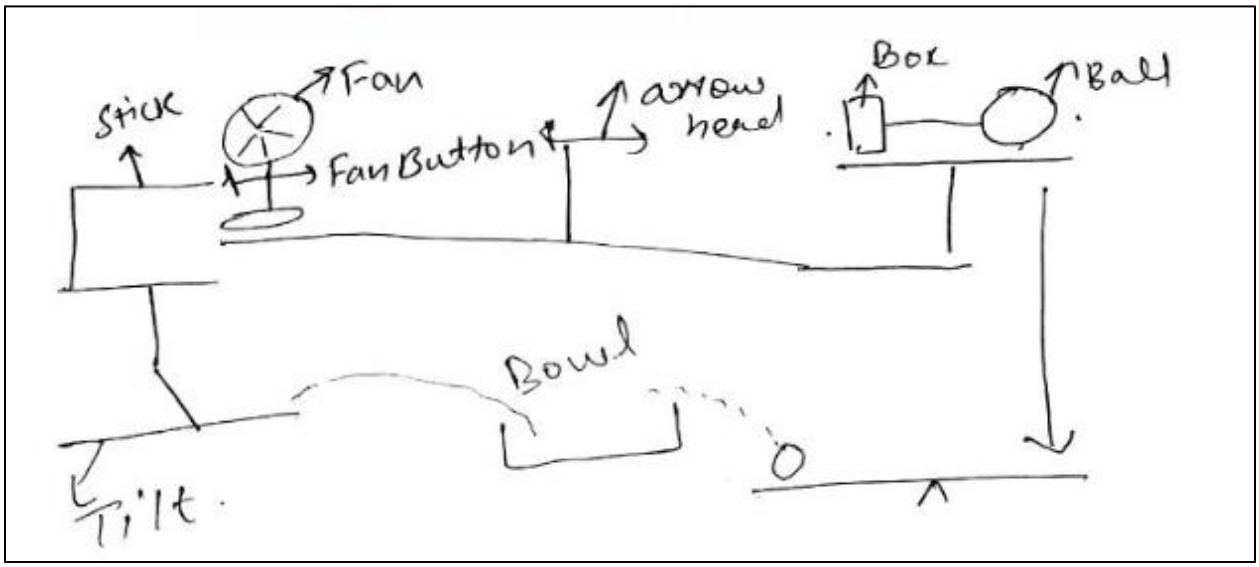


Figure 30: Design #20: Throwing item in bowl

In this design, there is a seesaw attaches with the stick, when the seesaw put some pressure from one side, a stick moves which presses the fan button, fan turns on. Air pressure of fan cause a small arrow head to hit the box, which slide on the surface and push the ball to drop it down on the seesaw. When the ball hit the seesaw, it pushes a stone and throw it into the bowl. Bowl has liquid which splash out and start the system again.

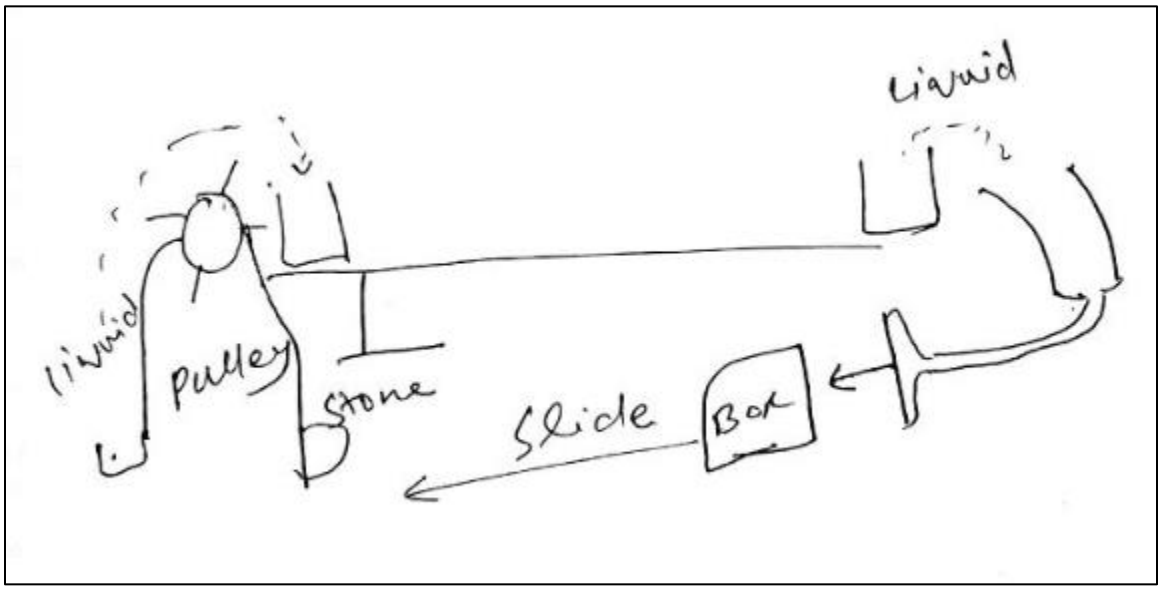


Figure 31: Design #21: Pulley moving box

In this design, the idea is to move the pulley which has liquid in onside and stone on other side. When stone falls down, liquid moves up, pass the liquid to the bowl places on height. When the liquid fills into the bowl, its weight increase. This bowl is present on the seesaw and there is another bowl present on the other end of seesaw. When first bowl fills with liquid and seesaw bends down, other bowl which has liquid, liquid fall down into the tube, tube has narrowed end, which creates the pressure and slit present on the end tube open. This cause box to slide on the surface.

Appendix C 1: DECISION MATRIX

Designs:	**Meets client's needs**	**Meets users' needs**	**Improves the existing designs**	**Total score**
Design#1	4	5	5	14
Design#2	4	5	6	15
Design#3	8	7	8	23
Design#4	5	7	4	16
Design#5	6	5	5	16
Design#6	5	4	6	15
Design#7	7	5	6	18
Design#8	5	7	7	19
Design#9	4	4	5	13
Design#10	9	5	5	19
Design with highest score	**Design #3**			

Score: 1-10
1 - least effective.
10 - most effective.

Appendix D2: PUGH CHART

Criteria	**Concept**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Reliable		+	+	-	-	S	-	S	-	-	+	+		+	+	-	+	-	-	+	+	+
Durable		+	-	-	-	-	+	-	S	-	S	-		-	-	+	-	+	-	+	-	+
20-75 steps		+	-	+	+	+	-	+	-	-	+	S	**D**	+	+	+	+	-	-	+	+	-
Each process last less than 2 minutes		-	-	+	-	-	+	-	+	S	+	-	**A**	-	S	-	S	+	+	-	+	S
Normal speed of the steps		S	+	+	-	+	-	+	-	-	-	+	**T**	+	-	-	+	+	+	+	-	+
Total size of 10ft by 10ft		-	-	+	+	S	-	-	+	-	-	S	**U**	-	+	-	+	S	+	-	-	-
Entertaining		-	-	+	-	-	+	-	S	+	S	-		+	+	+	-	S	+	-	+	+
Resettable		+	+	+	+	+	-	-	-	-	-	S	**M**	-	+	-	+	-	+	-	+	-
Σ+		4	3	6	3	3	3	2	2	1	3	2		4	5	3	5	3	5	4	5	4
Σ-		3	5	2	5	3	5	5	4	6	3	3		4	2	5	2	3	3	4	3	3
Σ s		1	0	0	0	1	0	1	2	1	2	3		0	1	0	1	2	0	0	0	1