
Sit At Desk
Direct Workflow!
Clock in @ 9.00a.m
Lunch Time !!
Have a break. Have a kitkat.
4 o'clock meeting
PLAYSET
Beat the Traffic Jam

Physics Independent Study Unit (ISU) Report

Rube Goldberg's Project

Closing a Toy Box after Playing

Germaine Tay 1007C10774 Period 2

Jaclyna Ang 1007C10033 Period 1

Neil Liew 1101C13590 Period 2

Soon Chee Loong 1007C79369 Period 2

Mr. Tan Swee Chuan

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How Do Children Close Their Toy Box Filled With Toys Using Physics Principles?

In our Rube Goldberg project, Germaine Tay, Jaclyna Ang, Neil Liew, and Soon Chee Loong group together to aim to close a toy box filled with toys using physics principles. These physics principles are demonstrated by 20 steps in this project. The first step starts off with a marble rolling off an inclined plane which will initiate the second step which will in turn initiate the next step until it initiates the last step which is the 20th step. At the 20th step, a toy box filled with toys is finally closed. The main reason for this is that a child may not want to keep his toys the way an adult would by just simply closing the toy box using his hands. He will want to play with a Rube Goldberg's machine every time he keeps his toys. Thus, the project is applicable in real life as a Rube Goldberg's toy meant for kids to pack their toys after playing. Each individual step is explained in detail below.

Step 1: A marble rolling off an inclined plane.

A marble is placed at rest on top of an inclined plane. However, the marble quickly rolls off the inclined plane due to gravity which pushes the marble downwards to roll off the inclined plane from rest.

Step 2: Projectile motion of marble into the basket.

The marble falls off the edge of the inclined plane at an angle that allows it to project right into a basket with just enough energy and momentum. It falls right into the basket as there are no forces acting on the marble which makes it to fly away from the upright board. Thus, the marble continues projecting in straight motion towards the basket and lands in it.

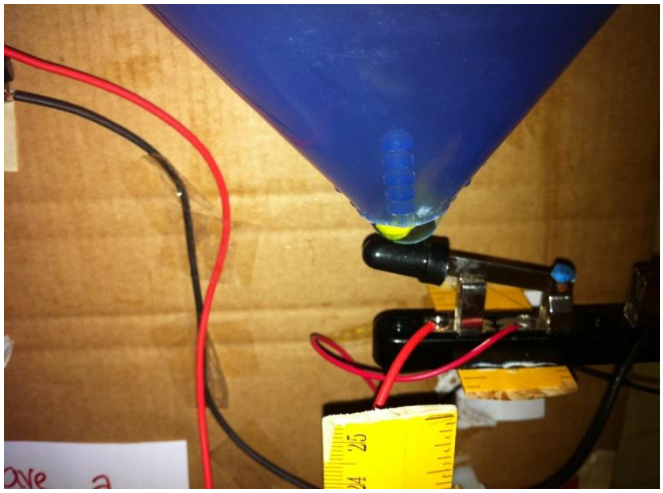
Step 3: A heavier weight of the marble in a pulley system removes an obstacle on a track which allows other marbles to move.

The basket which is connected to a pulley system now contains the marble and becomes heavier and allows it to pull the obstacle connected to the other side of the pulley. Therefore, the extra gravitational (mass times gravity) due to extra mass exerts more force to the pulley system and which results in higher tension force at the left side of the pulley system. Thus, the obstacle on the right side of the pulley system which is preventing other marbles to roll off the track due to gravity is pulled off the track by the thread from the pulley system towards the left side. Therefore, the other marbles are now free to roll down the inclined plane. This demonstrates a good example of conservation of energy as all the potential energy from one side of the pulley is converted to kinetic energy for the new marble to move.

Step 4: Marbles fall into a funnel to experience centripetal force and drops straight down at the bottom hole of the funnel with no horizontal motion.

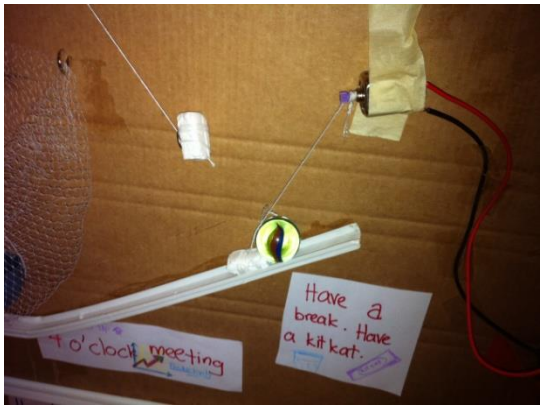
The marbles rolling off the incline plane falls directly into a funnel with both horizontal and vertical motion. However, it moves with centripetal acceleration due to centripetal force until it falls straight down the hole which is directly at the bottom of the funnel. The marble drops down the hole with no horizontal motion but only vertical motion.

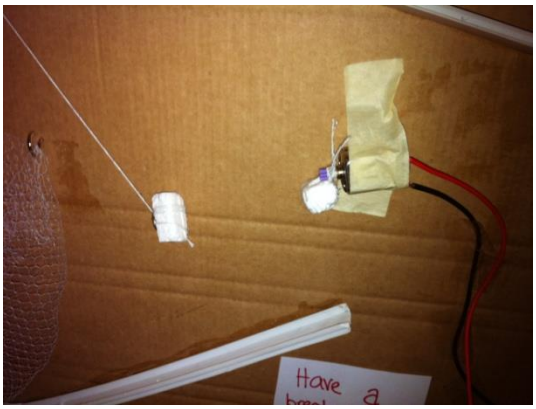
Step 5: Marble hits 90 degrees on the switch to activate it.



The marble which falls straight down with only 90 degrees of vertical motion allows it to precisely hit the switch downwards with maximum force due to gravity as all the forces are delivered to hitting the switch and closing it to activate the circuit. From the equation, $F\cos 180° = F(1) = F$. This means that all force is used vertically and none of the force is wasted due to horizontal force. Thus, the force from the small marble is maximized and should be strong enough to hit and close the switch.

Step 6: Switch activates the motor which winds up a thread and pulls off another obstacle which allows a big marble to move.





The switch which is now closed and triggered activates the motor to move due to the electrical energy produced by the batteries connected in the closed circuit. A thread which is tied to an obstacle which prevents a big marble from rolling off an inclined plane due to gravity is also tied around the motor. The motor which is rotating automatically winds up the thread around it which pulls the obstacle off the inclined plane with an upward force. Thus, the big marble is allowed to run freely down the inclined plane.

Step 7: A big marble hits the upper end of a movable ruler connected with a hinge which tilts and allows the lower end of the movable ruler to hit a smaller marble to move through a straight plane.

The big marble rolls down the inclined plane and hits the upper end of a movable ruler which is connected by a hinge to the end of the plane. The upper end of the movable ruler which tilts to the left automatically causes the lower end of the ruler to tilt to the right. The lower end of the ruler which tilts to the right then hits a stationary ball to move across a straight plane. The big ball's momentum is transferred to the stationary ball using the hinge. The higher momentum from the big ball due to its larger mass and increased speed allows the smaller ball to roll fast

enough through the straight plane as the mass is lower and thus has a higher velocity. This can be calculated from the equation: $m_1v_1 + 0 = 0 + m_2v_2$. Since $m_1 > m_2$, $v_2 > v_1$.Therefore, the momentum should be strong enough to allow the small marble to roll all the way of the straight plane.

Step 8: Small marble falls into the cup which is attached to the spring and is thrown to a new inclined plane.

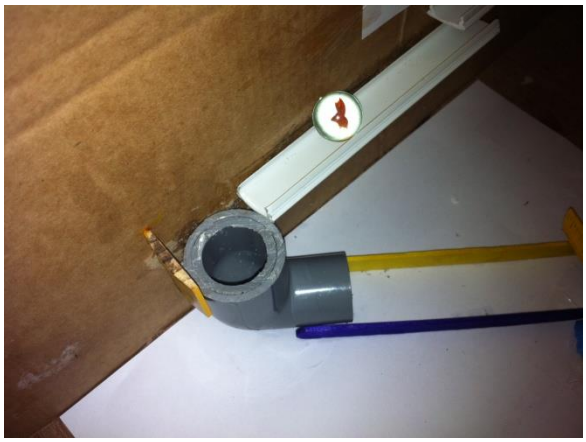
The small marble rolling off the inclined plane projects into a cup which acts as a catcher whereby the cup is attached to a spring. The spring which compresses due to the momentum of the ball generates elastic potential energy and launches the marble away from the cup from the same direction that it come from. However, it is launched at a lower position because the cup tilts downwards when the spring is compressing. Thus, the small marble is launched into the lower plane and rolls on it.

Step 9: Small marble falls straight down into a different plane which is parallel to the original plane.

The small marble rolling off a straight plane slows down as it is losing kinetic energy. However, it falls off into another parallel plane just few centimeters below its current plane. Thus, it gains kinetic energy because the potential energy due to gravity causes the ball to gain extra kinetic

energy that was converted from the potential energy due to gravity as it falls from the original plane to its next parallel plane. Thus, the marble is able to continue rolling off the straight planes although the force provided by the elastic potential energy of the spring in Step 8 is not enough due to the falling of the marble onto the second plane.

Step 10: Small marble falls into a pipe which directs it into a new ruler




The small marble then falls into a pipe which is L-shaped and rolls inside the pipe with centripetal acceleration due to centripetal force. The constant centripetal force provided to the marble inside the pipe gives the marble centripetal acceleration to turn to the opposite direction.

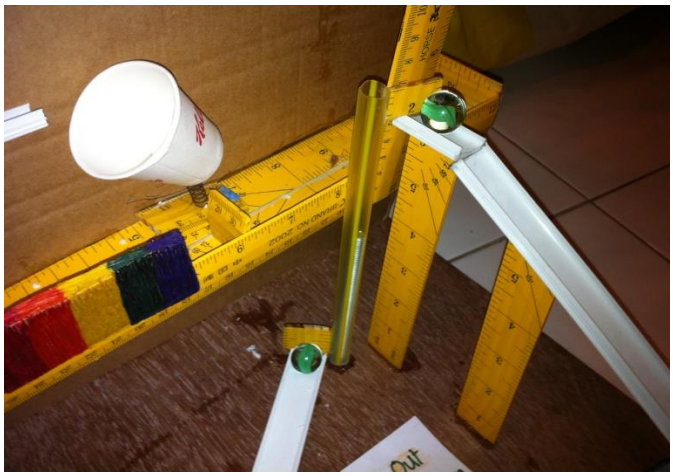
Step 11: Small marble hits a bottom ruler piece which is connected to a rotatable straw which moves the top ruler piece connected to the rotatable straw to hit a new marble to move.

The small marble which comes out from the pipe then moves forward and a small ruler piece connected to a straw which is rotatable which connects a different ruler. As the marble hits the bottom ruler which is connected to the straw, it rotates the straw which causes the top ruler piece to move and hit a new stationary marble to initiate it.

Step 12: New marble slides down on straight planes due to gravity which allows it to have horizontal motion and ends up hitting a new ruler.


New marble slide down from plane to plane due to gravity and the gravity allows it to have horizontal motion similar in the case in Step 9. However, after being initiated to move a little at the horizontal plane, the marble slides off to an inclined plane of the same direction which slides off to a new horizontal plane of a different direction due to gravity. The same case as Step 9 occurs which allows the marble to move a little on the new horizontal plane on the second direction and slides off to a new inclined plane which has the same second direction. This process is repeated a few times before the marbles falls off into an inclined plane tilted towards it.

Step 13: Small marble hits a bottom ruler piece which is connected to a rotatable straw which moves the top ruler piece connected to the rotatable straw to hit a new marble to move.



This step is similar to Step 9 as the small marble which comes rolling down the inclined plane hits a small ruler piece connected to a straw which is rotatable which connects a different ruler. As the marble hits the bottom ruler which is connected to the straw, it rotates the straw which causes the top ruler piece to move and hit a new stationary marble to initiate it.

Step 14: New marble slides and bounces off a trampoline.

The new marble then slides and bounces off the trampoline due to the elasticity of the trampoline to enter a toilet paper roll.

Step 15: New marble hits a big marble in a toilet paper roll transferring the energy for it to move.

After entering the toilet paper roll, the new marble hits a big marble which is stationary at the other edge of the tissue box. The big marble then rolls off the edge of the toilet paper roll.

Step 16: Big marble which is attached to the string drops and pulls the scissors to cut a paper.

The big marble which drops off the edge of the tissue box is connected by a thread to a scissors. A large gravitational force is exerted on the thread as the big marble drops off the edge of the tissue box from the equation $F_g = mg$, the large mass of the big marble exerts a big force towards the thread, this creates a strong tension force from the thread which pulls the scissors downwards for it to be able to cut the paper. The high pressure of the sharp point of the scissors allows the scissors to cut the paper easily.

Step 17: Car tied to paper is allowed to go freely and hits a domino block.

A car which is connected to the paper is allowed to roll down the road as the paper is cut. The car rolls easily down the road with a high velocity as its wheels greatly reduces the frictional force exerted on it and hits a domino. Conservation of momentum takes place as the fast moving car hits a heavier domino which allows the domino to stop the car from moving further but yet initiate a new domino.

Step 18: The domino block hits another domino block consequently and causes a domino effect.

The new domino hits another domino block which repeats this process consequently and causes a domino effect and this shows a good example of conservation of momentum.

Step 19: Last domino block hits a stationary marble, causing it to move down the inclined plane.

The last domino hits a stationary big marble which is also the last marble which allows it to move and rolls off the inclined plane.

Step 20: The last marble slides into a lever and removes the plane which is preventing the lever from moving. The lever then moves freely towards the heavier load and closes the toy box as it rotates.

The plane is stuck at a certain angle with the lever such that the forces are balance and thus the lever and the plane is at rest. However, the last big marble falls onto the lever and disrupt the balance forces. Therefore, the forces are no longer balanced and this causes the lever to move freely without being entangled by the plane. Therefore, the heavier load at the other side of the lever causes the lever to rotate sideways and closes the toy box as it does so.

Problems and Solutions

Problem 1: The original plan of Step 3 does not work well because the 2nd basket does not throw the other marble onto the new plane due to horizontal motion and the 2nd basket is not able to tilt sideways to throw the other marble.

Solution: Therefore, Step 3 was replaced with a new pulley system which simply brings of a load to the heavier weight.

Problem 2: Load from Step 3 is hard to be removed using the thread as the marble is not heavy enough to remove it. The frictional force between the load and the plane is higher than the downward force due to the weight of the marble.

Solution: Step 3 is replaced with a bigger catcher and a heavier marble which will definitely have enough force to remove the load from the plane. This allows the marbles to run freely as the obstacles are removed.

Problem 3: Ball does not fall straight down to activate the switch in Step 4 as the funnel was not tilted 90 degrees downwards but was slightly tilted to the right. This results in the ball flying sideways instead of falling straight down to the switch.

Solution: The funnel is brought back to tilting at 90 degrees.

Problem 4: In Step 7, the energy transferred from the big marble seems to be insufficient for the small marble to move across the long plane.

Solution: The movable ruler is not connected tightly. Therefore, not all momentum and energy from the big marble will be transferred to the small marble. Instead, a lot of energy will be lost in the form of heat and sound as the movable ruler simply reduces the force in the form of impulse with its longer reaction time.

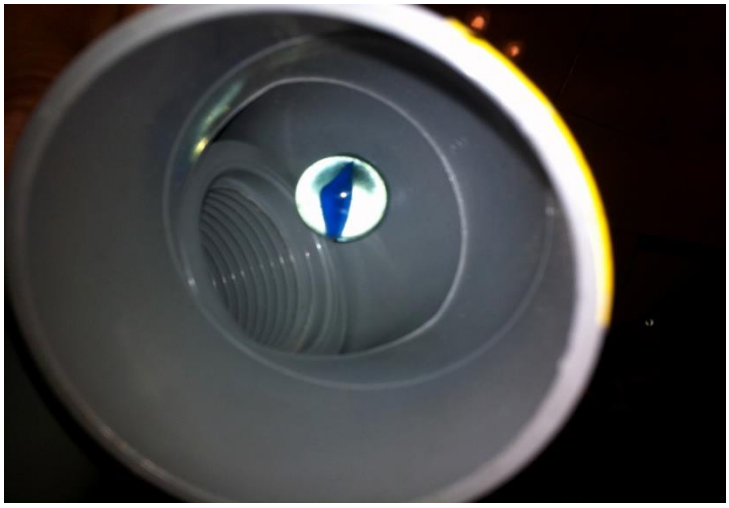
Problem 5: The wall is connected with metal pieces at one end to the base. This causes the wall to be tilted slightly to the other end due to the metal pieces which causes the marbles to drop off the plane due to the extra force towards you if you are looking at the project from the front view.

Solution: The wall is balanced with metal pieces at the other end of the wall to ensure that the wall is no longer tilted.

Problem 6: The force from the cup in Step 8 is not strong enough for the marble to roll all the way to the pipe in Step 10.

Solution: The distance between the parallel planes in Step 9 is increased so that the increased gravitational force gives the marble more momentum to roll all the way to the pipe.

Problem 7: The ball gets stuck in the pipe in Step 10 sometimes due to the friction of the pipes not being connected properly. Each pipe consists of a small side and a bigger side and is connected by connecting the smaller side of one pipe to the bigger side of another pipe. However, the interiors of the pipe are not perfectly connected as the smaller pipes which is inside the bigger pipes when connected obstructs the movement of the marble when the marble is sliding from the bigger pipe of the first pipe to the smaller pipe of the second pipe. The marbles hit the edge of the smaller pipe when rolling from the bigger pipe.



Solution: The pipes are connected so that the smaller pipe is connected first to the bigger pipe so that the ball will roll off the walls of the smaller pipe instead of the bigger pipe. Therefore, the ball does not have any obstacles due to the walls of the smaller pipe that is located inside the bigger pipe. Besides that, grease and oil is sprayed into the pipe so that the ball moves with little friction and is able to roll without stopping throughout its journey in the pipe.

Problem 8: The planes in Step 12 could not be perfectly connected to allow the ball to slide to the designated next ruler as the space available was not sufficient. The plan that was made needed the marble to slide to the next ruler at its designated area. Therefore, the planes had to be connected badly and the 2nd last plane of this step which connects it to the last plane of this step was not directly connected for the marble to roll into the last plane of this step.

Solution: Therefore, walls were attached to the last plane so that the ball is allowed to fall into the last plane despite not being directly above it.

Problem 9: The force from the small marble in Step 15 was not enough to even cause the big marble to move one centimeter.

Solution: The big marble was placed at the very edge of the tissue box so that it only needs a little force to fall off and pull the scissors to cut the paper in Step 16.

Problem 10: The weight of the big marble from Step 16 is not enough to move the scissors to cut the paper in Step 16. Moreover, the distance of big marble and the scissors was too far and the big marble ends up falling to the ground before it is able to stretch the thread to its maximum length to allow the tension force to pull the scissors. Besides that, the paper is too big for the blunt scissors to successfully cut it in one attempt. It was not known how to maximize the strength of the ball with the thread to pull the scissors. We were not sure if a longer thread would exert more energy, or a shorter one. Besides that, we were not sure if it is better for the thread to be extended before the ball drops or to be wounded up more freely before the ball drops for it to exert most force to close the scissors.

Solution: The big marble was replaced with a slightly heavier marble. The scissors was brought nearer which caused the planning of space to be changed and angled in a way that it is perpendicular to the position of the big marble when it drops. The paper is prepared to be as thin as possible so that it is easily cut by the scissors. Besides that, the thin paper is position as low as possible so that it is near the sharp edges of the scissors. After several trials and errors, we found out that the big marble and the thread exerts the maximum force to close the scissors when the thread is rolled up before the marble drops but not too long so that the marble does not touch the ground. The lower the marble drops, the better as the potential energy due to gravity is (mass x gravity x height) and the longer the distance of height, the higher the energy will be converted to elastic potential energy for the thread. However, the thread should not be too long until the energy available is changed into heat and sound when the marble hits the ground instead. Besides that, it is known that the marble exerts maximum force when the thread is rolled up instead of stretched before the big marble drops because if it is stretched, the big marble is actually reaching its lowest point while hanging in the air with the thread faster and simply swings to the ground instead of falling to the ground with maximum potential energy to be converted.

Problem 11: The force by the fast moving car is too high and does not allow the domino block to fall normally in Step 17.

Solution: The force of the fast moving car is reduced by allowing a large obstacle load to be placed between the domino block and the car in the pipe so that the force is reduced and the domino block is allowed to fall freely.

Problem 12: The marbles from various steps fall everywhere after completing its task and sometimes disrupt other steps.

Solution: A catcher or a wall is made so that the used marble falls into a safe area which does not disrupt any steps from activating.

Skills Learned

1. We learn to **apply Physics laws and principles** in the construction of this Rube Goldberg project. We learn how to transfer our knowledge to real life application. Several different theories and principles were utilized in the construction of the project. Whenever a step does not work, we learn to think using physics laws on the possibilities that the steps are not working and try to solve them based on our proposed theories of faults in the steps. Then, we learn to see if our theories is true by testing the steps.

2. We also learn to be **creativ**e in planning our steps. We have to be innovative in connecting the different steps together so that they will work continuously. We also have to be resourceful in solving the problems that we face. We have to constantly think of creative solutions to the many problems we faced.

3. We also found out about the importance of **teamwork** when doing a group project. It is very important for each and every group member to pull their own weight and complete the duties and responsibilities assigned to them. Besides, we learn to cooperate and work with other people with different mentality and thinking. We also learn to be open and accept each other's ideas, even if we do not agree with them.

4. Lastly, we learn to **manage our time and resources** properly. We have to plan our time and budget in order to complete this project. We learn to make use of what we already have and not waste money to buy materials that are already available. We also need to plan our schedule so that we have ample time to work on the project and it will not interfere with our other projects and responsibilities.