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Rube Goldberg Machine Report

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ABSTRACT. *Rube Goldberg Machine A Rube Goldberg machine, named after American cartoonist Rube Goldberg, is a machine intentionally designed to perform a simple task in an indirect and overly complicated way. Usually, these machines consist of a series of simple unrelated devices; the action of each triggers the initiation of the next, eventually resulting in achieving a stated goal. 1Due to the special situation because of the epidemic around the world this year, we have to have this program online, therefore, the machine is not in real world but is a simulation by blender 3D 2.8. And to track and analyze the physics underlying individual step. The main purpose of my Rube Goldberg machine is to build up a device with several steps to push a switch in the end. There are also constraints that the steps must contains 7 part in physics which are elastic collision, inelastic collision, conservation of momentum, conservation of energy, projectile, circular motion and torque.*

KEY WORDS: Rube Goldberg machine, blender 3d, track

Methods

Before get started to build the simulation in blender, I made the draft plan for this machine and it was like figure 1.

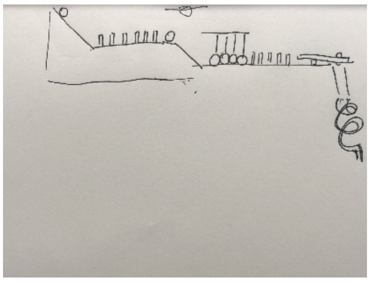

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Fig 1

And to get start, I have to learn about how to use blender, which took me a lot of time because it was the first time using this software.

I learned about how to add a mesh in, how to scale a mesh, how to shift and rotate, etc.

Also, how to use tracker is also a challenge for me.

For the part of analyzing, we joined several sessions to study the physics concepts and application. We joined topics of speed, velocity and vectors; momentum and center of mass; Newton's laws and free body diagram; collisions etc., which is not only useful in this project but also helpful to other physics study out of this project.

After these preparations, we simulated the machine in the blender 3D, rendered and output the video of simulation.

We analyzed our simulation of this Rube-Goldberg machine using Tracker and recording each step of the machines and tracking moving parts.

Discussion

I use different parts in the machine to illustrate the physics.

Physics concept	Description of the step
Elastic collision	When a ball rolled down for a slope and collide with the other balls the change(decrease) in its velocity is also the change in the other one (increase). Both the momentum and energy are conserved, so I consider it as the example for elastic collision.
Inelastic collision	When a ball collides with the other one, at the moment, they stuck together and move together, so this is inelastic collision.
Conservation of energy	When the ball is rolling down a slope, which is set to be frictionless, all the GPE transformed into KE, so the energy is conserved.
Conservation of momentum	Same as the elastic collision, the step which seems to be a Newton cradle, the kinetic energy of the launching one is the

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	same as the last one just after the collision.
Projectile	When the ball falls down, it falls on the slides, before contacting with the slides, the ball is going through projectile.
Rotation	When the ball is sliding down in the spiral2, if look from the upside right beyond this, the ball can be seen in the circular motion
Torque	When the domino falls down on the long board, the domino is providing an anticlockwise force which is the example of concept of torque

Table 1 (7 concepts and steps)

Analysis in tracker

Elastic collision

The example illustrating the elastic collision is the Newton’s cradle

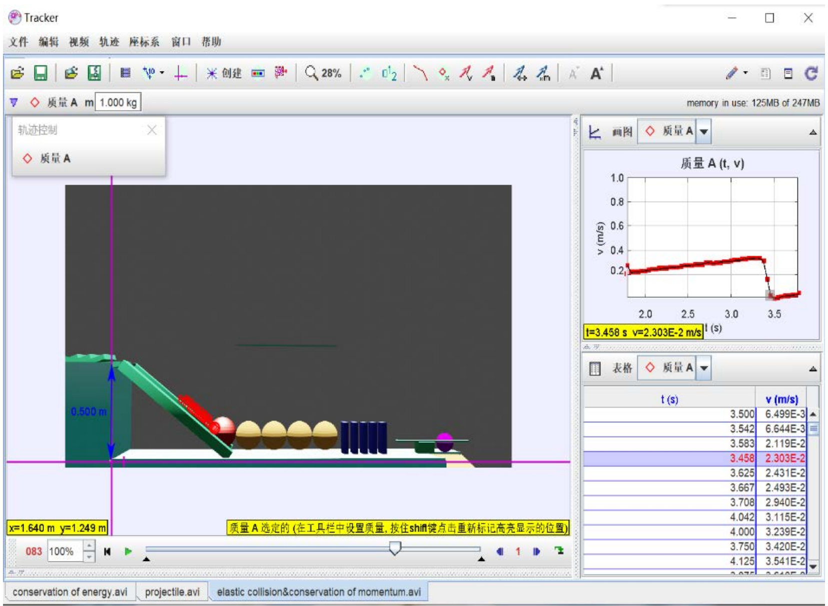

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Fig 2 elastic collision

From the data we got from tracker, before the collision, at t=3.3s，the velocity of the red ball is 0.3 m/s, but after the collision its velocity is approximately zero, before the collision, at t=3.3s, the velocity of the last yellow ball is 0, but after the collision, the velocity becomes 0.3m/s. Then, we can know its elastic collision.

Inelastic collsion

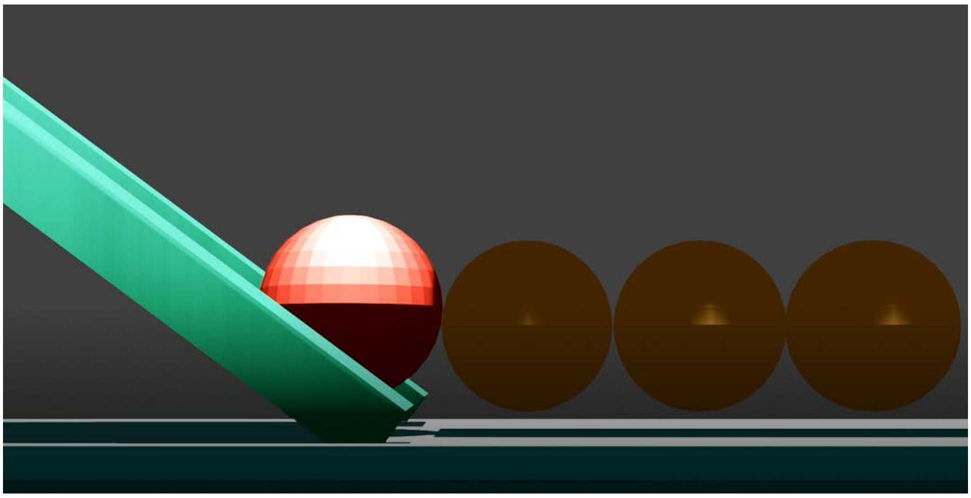

Fig 2 inelastic collision

The collision between the red ball and the first yellow ball, just after the collides they will stuck together and move together, so the collision should be considered as one inelastic collision.

Conservation of energy

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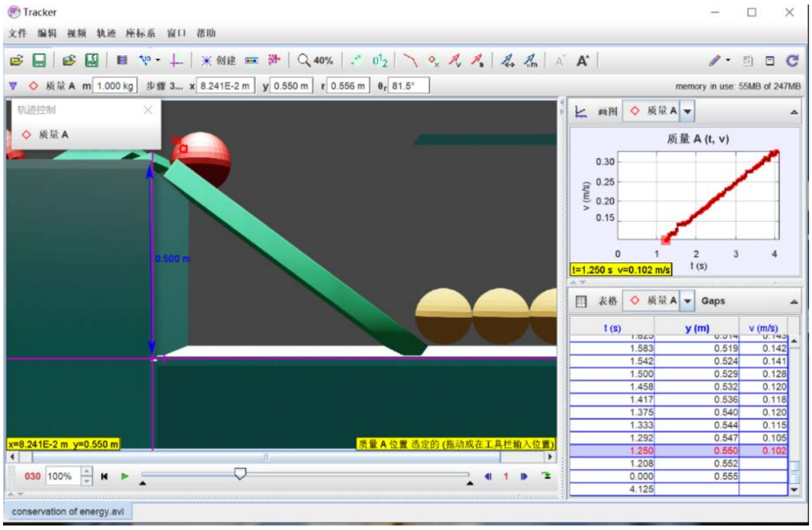

Fig 3 change in velocity of the red ball

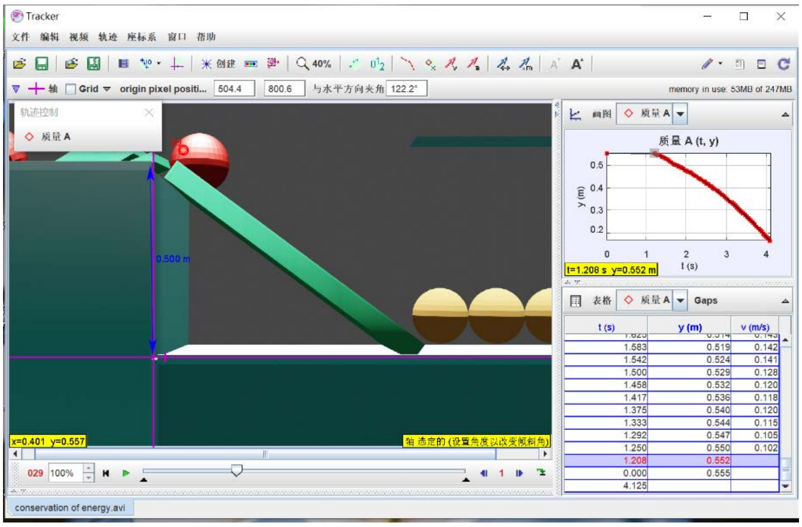

Fig 4 change in height of the red ball

This is an example of conservation of energy, because in the blender setting, I set this friction to zero, so in this step, the energy can only be converted from gravitational potential energy to kinetic energy, and we already know that the mass is 5 kg, just by measuring the velocity, we can calculate the initial kinetic energy and

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the ending kinetic energy by KE = 1/2mv ^ 2, and then measure the change of the height to calculate the change of the gravitational potential energy by GPE = mgh

Change in GPE : 0-0.5x9.8x5=-24J

Change in KE: 0.5x5x3^2-0=23J

Their changes are equal, so we show that energy is conserved, and the decrease in its gravitational potential energy equals the increase in its kinetic energy .

1. Conservation of momentum

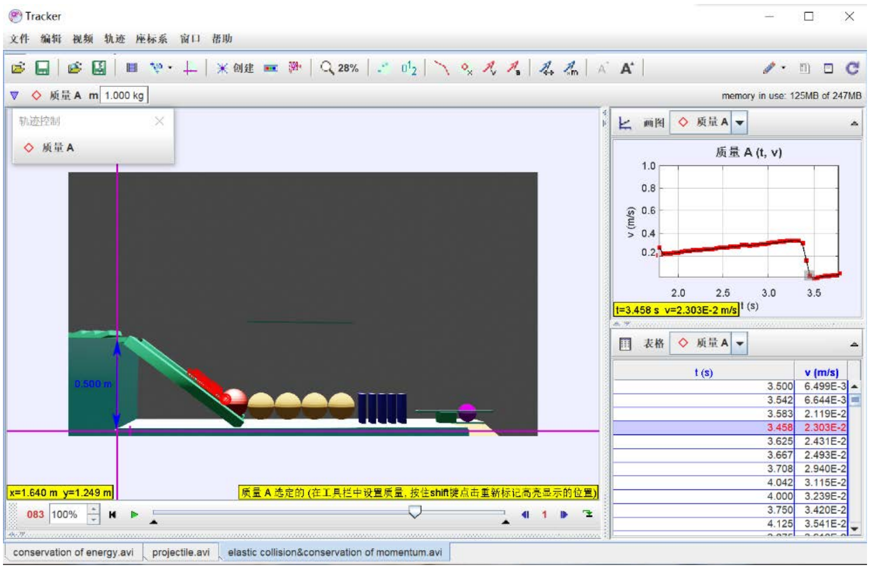

Fig 5 conservation of momentum

Just like the elastic collision in the first step, we can use the data to calculate the momentum before and after the collision, the velocity of the Red Ball before the collision is v 1, the velocity of the Yellow Ball is 0, and they all have mass m, so the momentum is mv1 + 0 = mv1 after the collision, the velocity of the Red Ball is 0, the velocity of the yellow ball is v2, so the momentum is mv2 + 0 = mv2

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The data shows that both v1 and v2 are 0.3 m/s

So we can conclude that the momentum before and after the collision is conserved.

2. Projectile

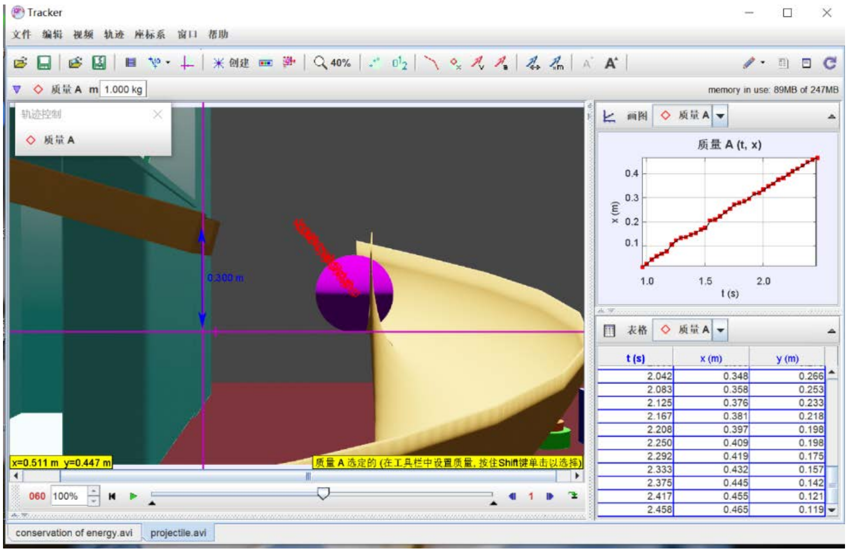

Fig 6 projectile

In this step, the ball leaves the ramp and lands above the spiral, and before it lands in the spiral, the process in the air can be seen as a projectile motion in 2D.

Just from the image, we can see that the displacement in the x-axis of the projectile is a straight line, the slope of the displacement is the velocity, and the slope of the image is a fixed number, it has the same velocity in the x direction.

Because in the process of projectile motion, the ball is only subject to the vertical force of gravity on it, but the horizontal force is not, so its horizontal velocity is constant and the horizontal acceleration is zero.

3. Rotation

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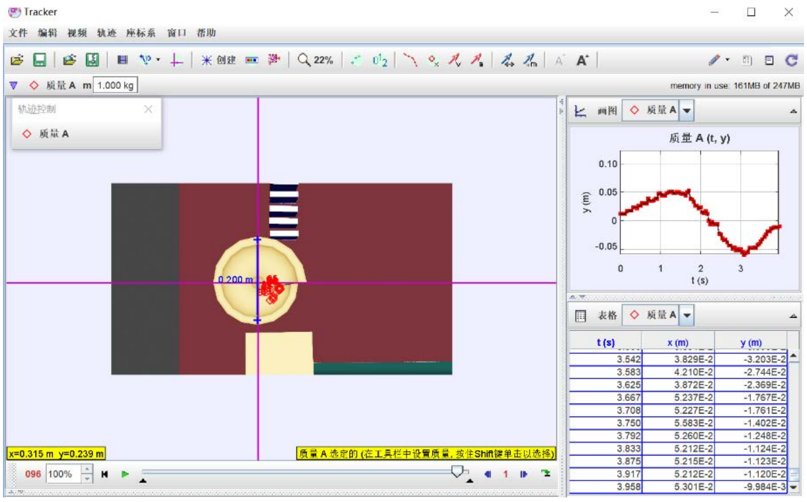
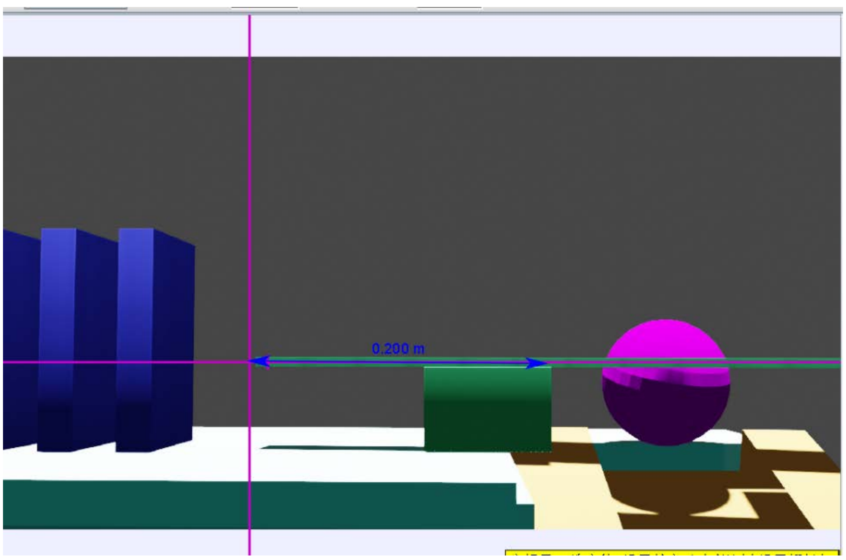


Fig 7 Rotation

The time for the ball to finish one round of the circle is 4s, so the angular velocity is $2\omega = \frac{2\pi}{4} = 0.5\pi$.

4. Torque



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When the last one of domino falls down on the longboard, it exerts a anticlockwise direction force on the far left end of the board, the pivot of the lever being the point in the upper left corner of the block holding the long board, and the force on the other clockwise direction being the force of gravity on the board

Conclusion

In this project, I learned a lot, not only in class to learn the knowledge of physics, but also learned to use in real life and machines, this is a very rewarding and useful harvest, however, looking back on the whole process of the project and the process of analysis and thesis writing, there are some unsolved problems and shortcomings in my methods. For example, when tracker was tracking, I didn't have a uniform set of length markers, which led to imprecision, and so on, because this was my first experience with this kind of project, it is hoped that when similar studies are conducted in the future, the same problems can be avoided in this experience. On the whole, I feel very satisfied with this project. Not only am I very satisfied with my performance, but I feel a strong sense of accomplishment and satisfaction in acquiring knowledge and making progress. I also have a deeper understanding and understanding of physics, and more want to continue to explore and learn physics.

References

[1] https://en.wikipedia.org/wiki/Talk:Rube_Goldberg_machine
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