2.2
3D Printing-Balloon Car

In this lesson, students will learn to design a balloon-powered car. They will understand the concepts of force, motion and Newton's third law. Also, students will learn the basic force analysis and recognize the influence of gravity and friction on the motion of objects. Teachers can hold a car competition of the balloon-powered car after the study.

Subject	Physics	**Grade Levels**	6-9
Difficulty	Intermediate	**Duration**	45 mins/ class, 4 classes in total

01 Learning Objectives

1. Understanding the basic principles of Newton's Third Law
2. Understanding the force of a car in motion and at rest
3. Learn to use Tinkercad to design models

02 Next Generation Science Standards

• 3-5-ETS1-1 Engineering Design Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
• 3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
• 4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.
• 4-PS3-4 Energy Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
• MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
• MS-PS2-2 Motion and Stability: Forces and Interactions. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
• MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

03 Other standards

Common Core State Standards

• 3.MD.D.8. Measurement & Data Solve real-world problems involving perimeters of polygons, including finding the perimeter given the side lengths, finding an unknown side length, and exhibiting rectangles with the same perimeter and different areas or with the same area and different perimeters.
• 4.G.A.1 Geometry Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.

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Creativity and innovation
1a. Apply existing knowledge to generate new ideas, products, or processes.
1b. Create original works as a means of personal or group expression.

04 Preparation

Teachers:

(Per person)

1x A computer with Internet access and Snapmakerjs software
1x Finished balloon powered car
1x Balloon
1x USB disk
1x Measuring tape
1x A4 paper

Students:

1x Internet-accessible computer with Snapmakerjs software
1x Pencil
1x Compasses
1x Eraser
1x Ruler
1x Balloon
1x A4 paper

Equipment requirements:

- Snapmaker Original 3-in-1 3D Printer (3D printing module)
- 1.75mm PLA Filament

05 Related Tutorial

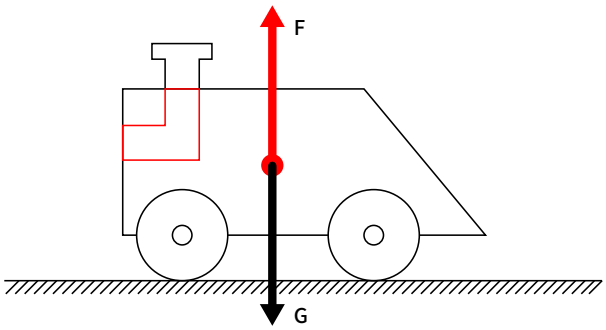
- Snapmaker Original 3-in-1 Printer 3D Printing Instruction:
  https://manual.snapmaker.com/3d_printing
- Tinkercad Getting Started:
  https://www.tinkercad.com/learn/designs/learning

06 Empathize

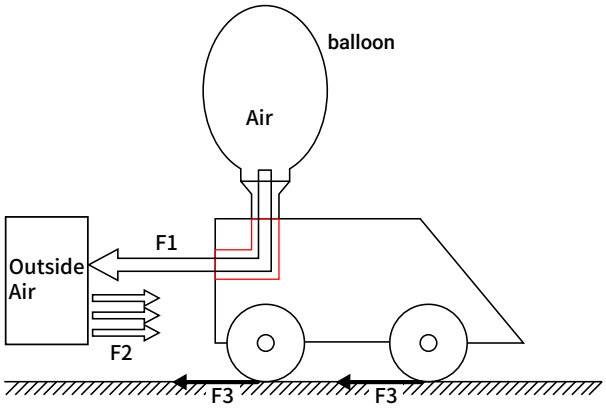
Newton's Third Law: The action and reaction force between two objects is always equal in magnitude and opposite in direction, acting on the same straight line. For example, when rowing, the pump pushes the water backward (action force), and the water pushes the pulp and the boat forward (reaction force) so that the boat can move forward. Similarly, the launch of rockets is also an application of Newton's third law. When the rocket fuel burns, it produces a large amount of gas, which collides with the external air to produce a counter-thrust to push the rocket into space. Since the reaction force of air can launch a rocket into space, can we use air to make the car move?

07 Define

Show the balloon-powered car to students and analyze the force of the car in the static and moving state, and discuss the factors affecting the car movement. Then have students design the balloon-powered car according to the influencing factors.



The force analysis of the car in static: When the car is at rest, the force it receives is mainly the gravity (G) and the support force (F) of the desktop. The gravity is downward and the support force is upward. The two forces interact in a straight line, and the two forces are balanced so that the car is in a special state of motion - stationary.



The force analysis of the car in motion: When the balloon is deflated, the released gas (F1) interacts with the external air, giving the car a recoil force (F2). The original equilibrium state of the car is broken because of the recoil force, and the car changes from a static state to a moving state. At the same time, when the car moves forward, the friction force (F3) obstructs the motion between the car and the contact surface (ground) occurs. The factors affecting the friction force (F3) are the weight of the car and the roughness of the contact surface. The heavier the car, the rougher the wheel and the contact bottom, the greater the friction force. When the recoil force is greater than the friction force, the car will accelerate forward under the combined action of the force. However, with the emission of gas in the balloon, the recoil force decreases slowly. Under the action of friction, the car decelerates until it stops, which returns to the static state, and the force acting on the car returns to the equilibrium state.

Main parts of the balloon-powered car are as follows:

- 1x Car body part（air nozzle and airway included）
- 2x Wheel axles
- 4x Wheels
- 1x Balloon

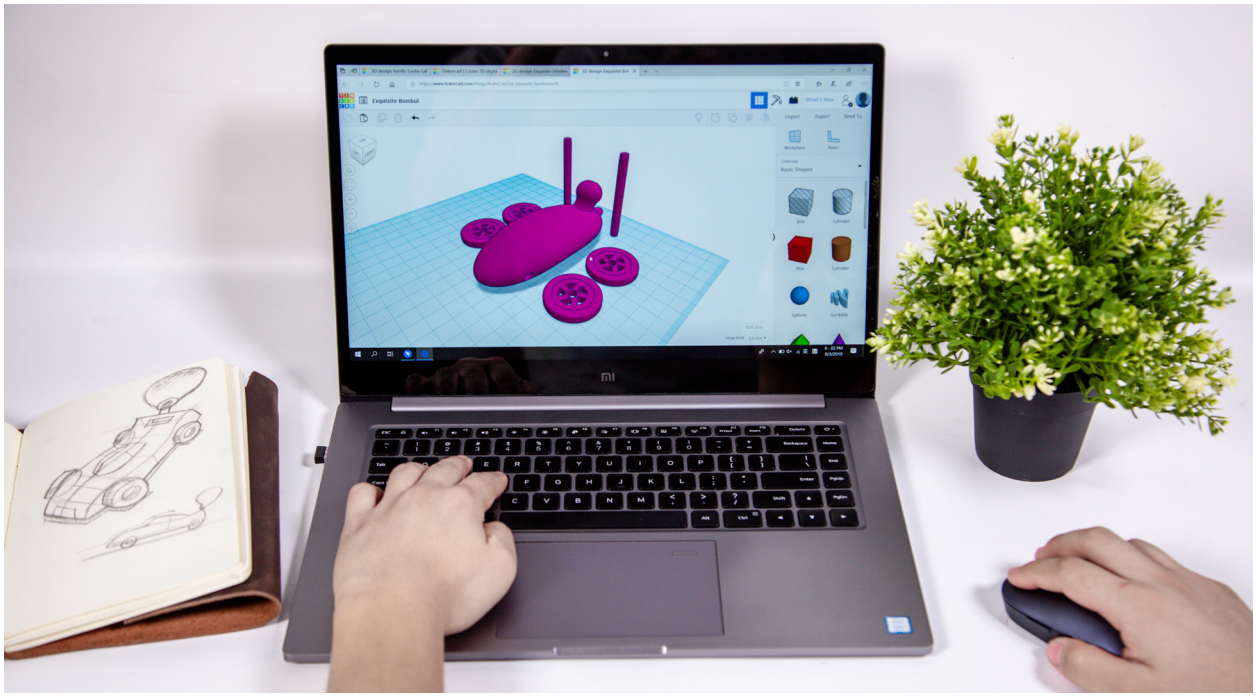
Hold a balloon-powered cars race, and judge by the lengths of the cars' single movement.

08 Ideate

Have students sketch their design from different angles of cars on papers, and mark the size for modeling.

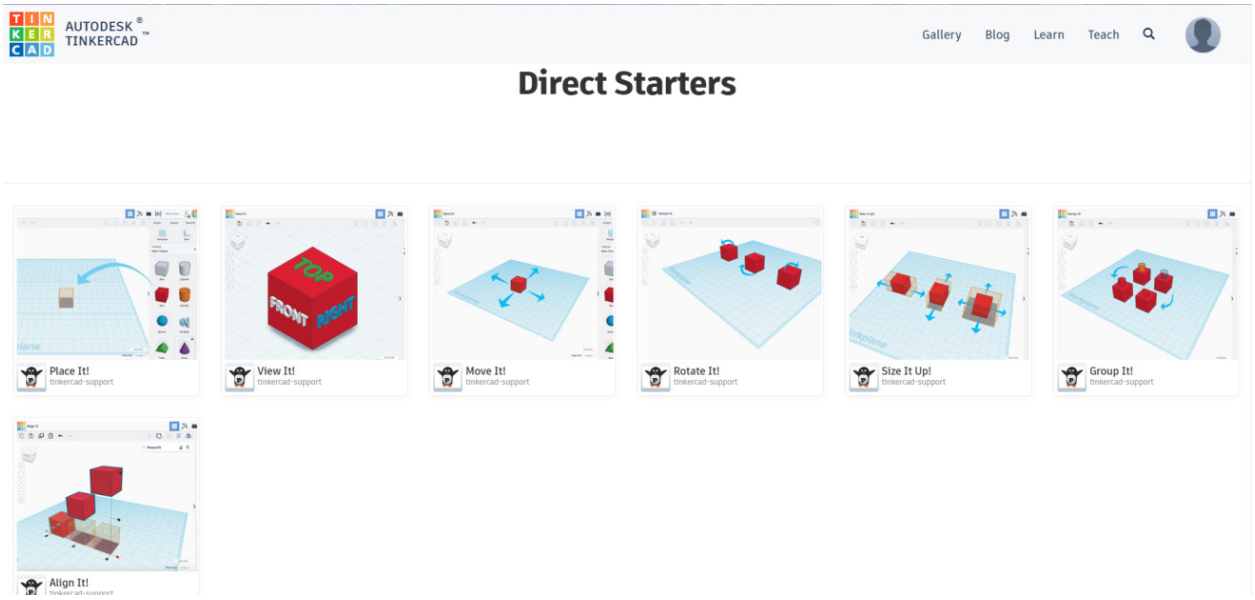
09 Prototype

Use Tinkercad to design the model of balloon-powered cars.



Step 1: Tinkercad Preparation

Guide students to complete the introduction learning on Tinkercad (See "Related Tutorials") and know the basic functions of Tinkercad.



Step 2: Balloon Powered Car Design

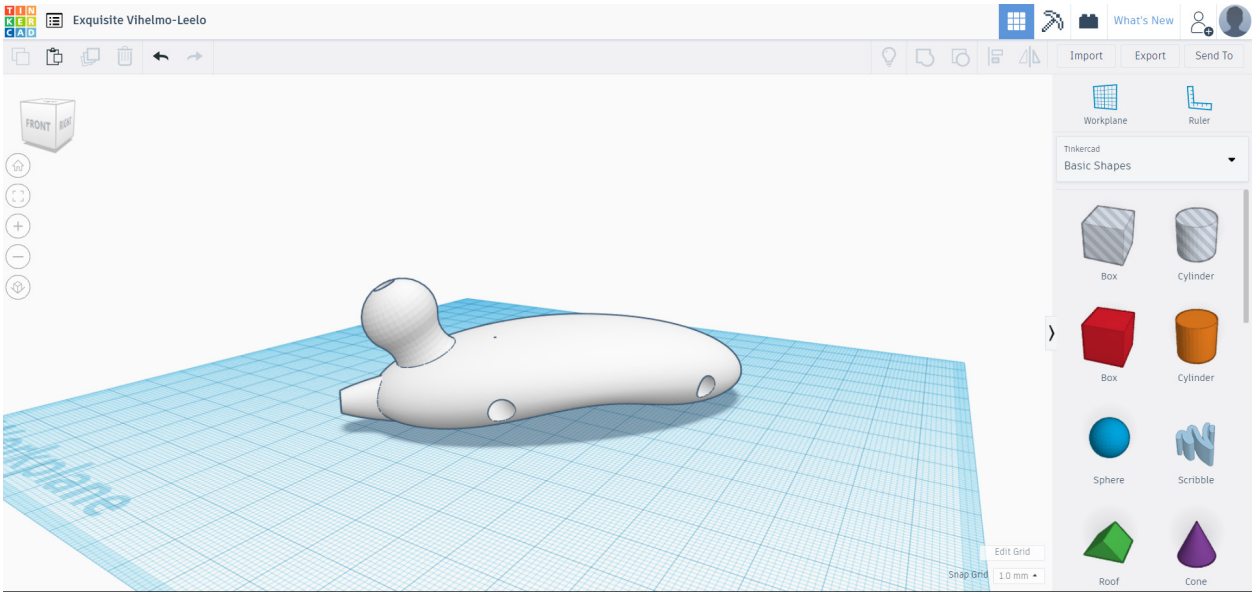
Guide students to sketch the balloon-powered car in Tinkercad.

1) Car Body Design

Design the car body based on its sport characteristics.

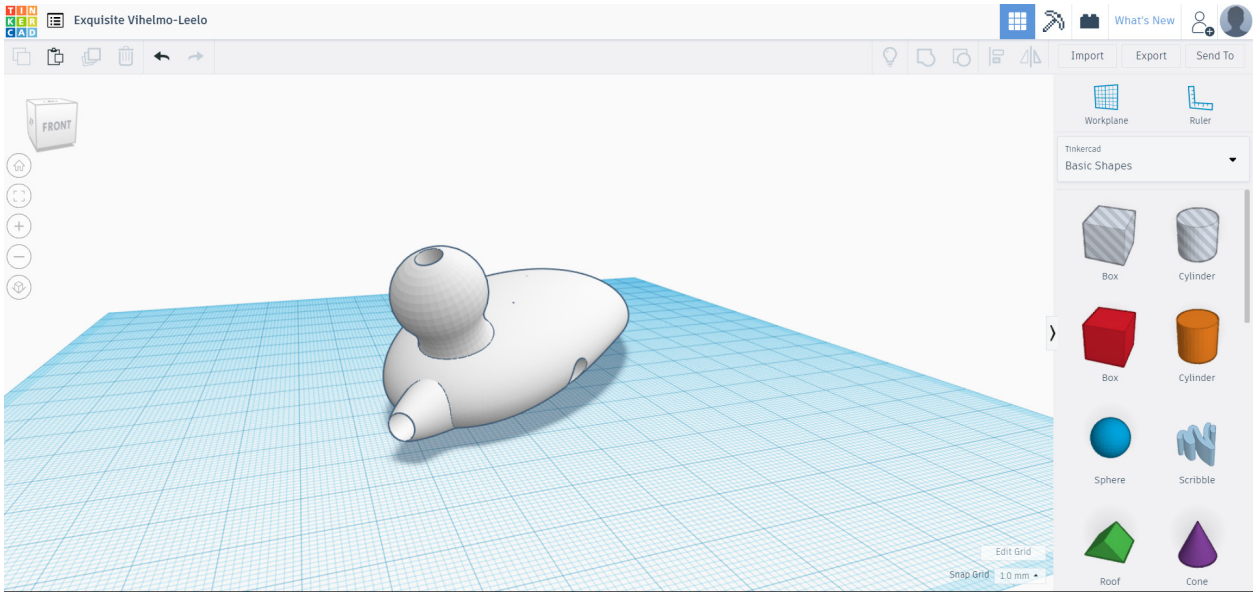
Key points of Design:

•The bottom part should have a certain thickness for the design of axle grooves (the two openings shown below).



2) Air Nozzle and Airway Design

Modeling of air nozzle and airway: The main purpose of the air nozzle design is to install and fix the balloon, and to adjust the direction of air injection through the airway, so the car can get the forward impulse.



Key Points of Design:

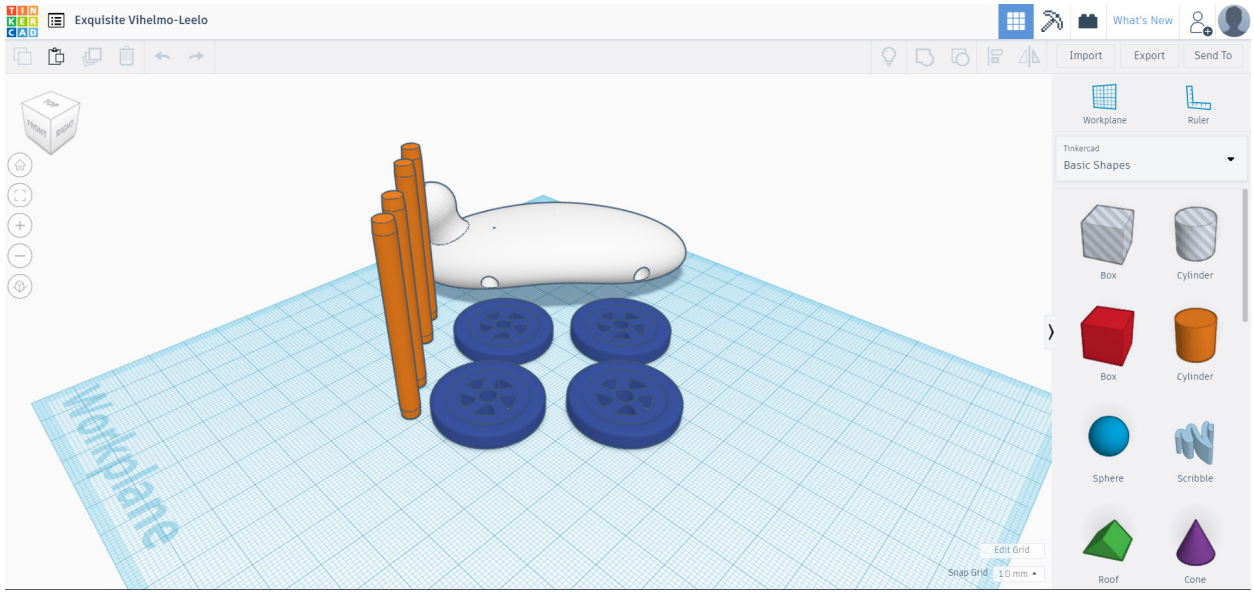
•Design the convex structure to fix the balloon on the intake port.

• The outlet is designed in the middle of the back of the car.

> **Tips**
>
> Pipeline model can be found in "Shape Generators - Selection" for airway design.

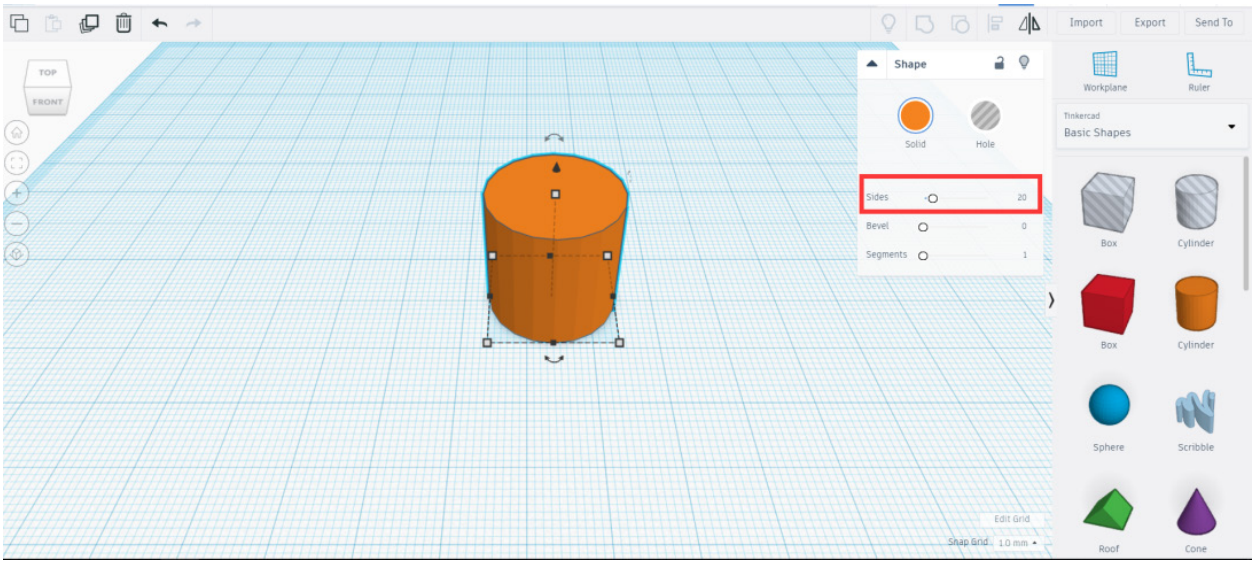
3) Wheels and Axles Deign

Design the axles、axle holes and wheels according to the sketch.

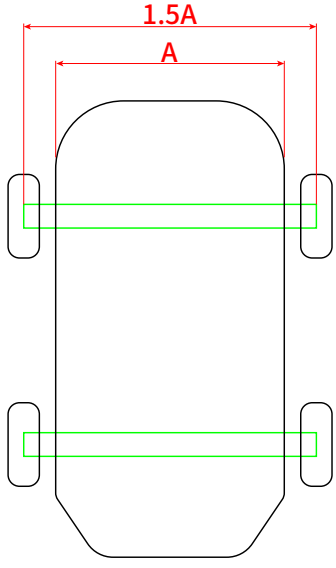


Key Points of Design

• The number of edges of a cylinder will affect the surface roughness, then affecting the sliding friction. Therefore, set the maximum number of edges, the motion resistance will be the minimum.



• The diameter of the axle hole at the bottom should be about 0.5mm larger than the axle.
• The length of the wheel axle is (1.5A) 1.5 times the body width (A) (as shown below).



Tips

Operate in groups with hollow cylinders to make the axle holes of car bodies.

Step 3: File Export

Click the “Export” button at the top right of the Tinkercad, generate the file in OBJ or STL format and download it to your computer.
• If the structural model is small, we can put them in the same file and print together.
• If the models are big, we need to export and print them in separate files.

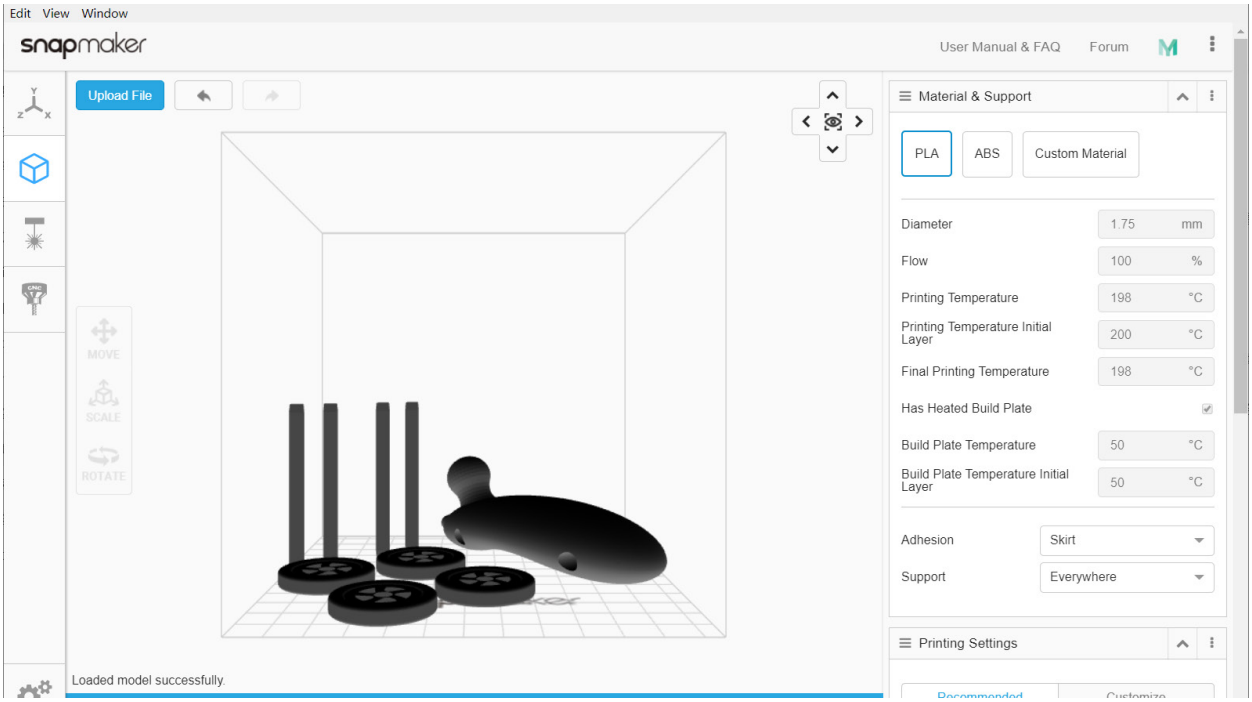
10 File Processing -3D Printing

File-processing is processing the OBJ and STL file through Snapmakerjs and convert it to a machine recognition file. First of all, you need to open the software and enter the 3D Printer G-code Generator interface.

Parameters settings	
Model: Balloon powered car	
Import method	Upload files
Material	PLA
Support	Everywhere
Printing Settings	Custom- Normal Quality
Modify parameters based on Normal Quality	
Infill density	8%
Initial layer printing speed	10mm/s
Inner wall speed	30mm/s
Travel speed	40mm/s
Initial layer travel speed	30mm/s

Tips

The higher the filling density, the heavier the body weight, and the longer the printing time.



- Click on “Generate G-Code”.
- Observe the material to ensure the model is printed efficiently.
- Click on "Export G-code to file"， name it as “BalloonCar”, and duplicate it to the USB disk.

11 3D Printing

Use Snapmaker Original 3-in-1 3D Printer to print the car. (3D Printing Module)

Step 1: Safety

Please read the safety instructions in the appendix before using the printer.

Step 2: Printer Preparation

•Install 3D printing module and heated bed of Snapmaker Original 3-in-1 3D Printer.
•Insert the USB disk and turn on the printer.
•Level the heated bed.
•Load PLA filament. Mind the nozzle since it is pre-heated before the PLA is installed.

Step 3: 3D Printing

• Choose "Files" on the touchscreen and select the design file.

• Complete.

Step 4: Balloon Powered Car Assembly

• Assemble the balloon-powered car.

• Prepare all parts of the balloon-powered car.

• Complete.

• Install balloon, test function.

12 Activity-Balloon Powered Car Race

Place the measuring tape on the ground and draw out at a certain length, set the starting point as well. Have each participant race the car in order. Teachers record the distance of each car for the ruling.

13 Share

Have students discuss their projects from the following aspects:
• What is the force effect on car movement?
• Does the car work?
• Is there any room for optimization?
• Thoughts of the study.

14 Development

1. Besides rockets, hovercraft also applies Newton's Third Law. With the concept learned in this lesson, encourage students to make an aerodynamic ship using 3D printing?
2. Ranging runway: Inspire students to design a speed measuring runway to measure the speed of the aerodynamic vehicle using Arduino, IR sensor, digital tube, and 3D printing. Start the timer from the car triggers the first IR sensor and stop timing when it reaches the second IR sensor, and use the digital tube to display the speed.