Square Wheels

Who said you can't roll around on square wheels? Explore the geometry behind different 3-dimensional shapes and how they work together to create a square-wheeled car!

TEKS:

MATH 2.9A: The student is expected to find the length of objects using concrete models for standard units of length.
MATH 3.5D: The student is expected to determine the unknown whole number in a multiplication or division equation relating three whole numbers when the unknown is either a missing factor or product.
MATH 3.6A: The student is expected to classify and sort two- and three-dimensional figures, including cones, cylinders, spheres, triangular and rectangular prisms, and cubes, based on attributes using formal geometric language.
MATH 4.6A: The student is expected to identify points, lines, line segments, rays, angles, and perpendicular and parallel lines.

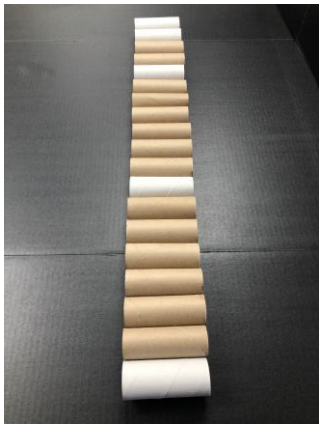
Materials:

- Foam board (4 x 30 inches)
- Hot glue gun and hot glue sticks
- Paper clip
- Pencil
- Poster board or cardstock (8 x 10 inches)
- Ruler
- Scissors
- Straw
- String (12 inches)
- Thumb tack
- 20 toilet paper roll tubes
- Utility knife
- 2 wooden skewers

How To:

Creating the round road

1. Create the road base by cutting a piece of foam board into a 4 x 30-inch-long rectangle.
2. Align 20 toilet paper rolls along the base side-by side. The rolls should lay horizontally along the 4-inch base width with the roll openings along the long 30-inch length of the base.
3. Using a hot glue gun and hot glue sticks, glue the toilet paper roll tubes to the road base making sure each tube is touching the adjacent tubes. **Safety: An adult should assist when using hot glue.**

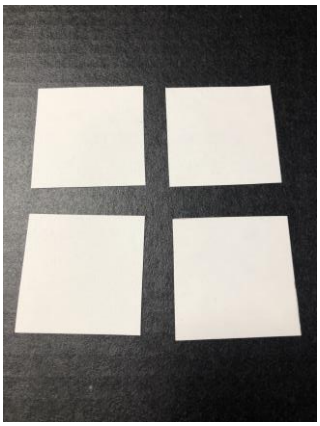


Calculating the square wheels

1. Measure the diameter of a toilet paper roll. Record the measurement.
2. Select three more random toilet paper rolls to measure their diameters and record the results.
3. Standard toilet paper tubes should each have a diameter of about 1 11/16 inches. If the tubes in your project follow this approximation, then the wheels should made from 2-inch squares. If your toilet paper roll tubes measure a different diameter, then the wheels will need to be calculated differently.
4. To calculate the length of the square wheels, follow the formula:

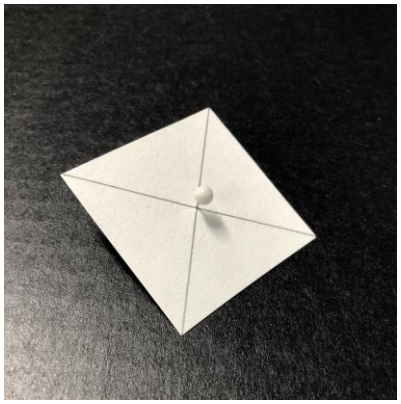
$$Length\ of\ square = 1.2\ x\ length\ of\ tube\ diameter$$

5. After the length of the square is calculated, measure and draw four squares of the corresponding lengths on poster board or cardstock. Cut out the squares to create four wheels.

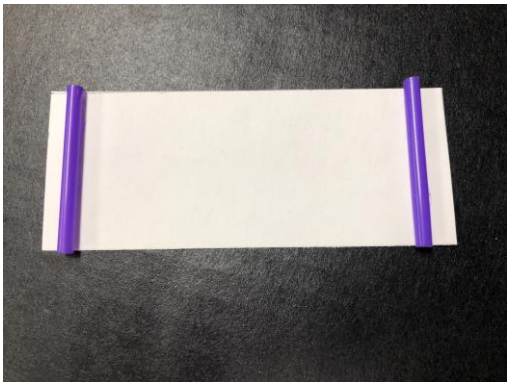


Assembling the car

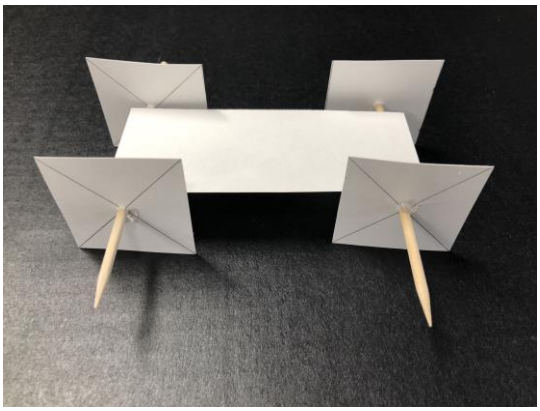
1. Using a ruler and pencil, draw an "X" on each wheel by drawing a line connecting the opposite corners on each square wheel. The center of the "X" you created with the lines will be the center of your wheel.



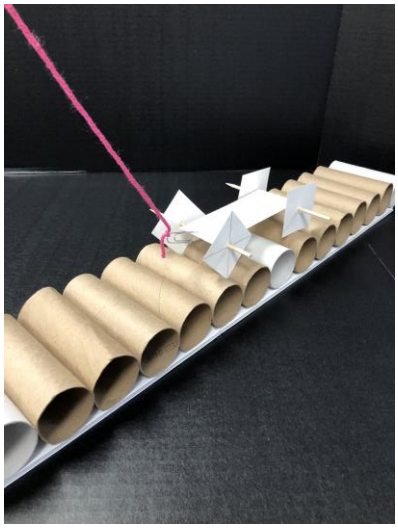
2. Make a small hole in the center of each square wheel by using a thumb tack to poke through the center. Try to avoid bending the square wheel in this process.
3. Cut a 2 x 5-inch rectangle from the remaining poster board or cardstock to be used as the body of the car.
4. Measure and cut two 2-inch-long pieces of a straw.
5. Glue each straw piece at each end of the car base about 0.5 inches from each end. **Safety: An adult should assist when using hot glue.**



6. Measure and cut each skewer to 5 inches long from the pointed end. To cut the wooden skewer, use a utility knife or use scissors to make an indention in the wood and then bend the skewer at the indention to snap the skewer into pieces.
7. Slide one square wheel onto the pointed end of the 5-inch piece of skewer until it is about 1 inch from the cut end. Slide the pointed skewer end through one of the straws and place a second square wheel onto the pointed end. Repeat this for the other set of wheels.
8. Place the car on a flat surface. Adjust all four wheels to be close to the body of the car and aligned with one another. The wooden skewer axle should turn easily in the straws.
9. After all four wheels are aligned, make sure the square wheels are also perpendicular to the axle. A small amount of hot glue can be used to fix the wheels to the axle and maintain their alignment. **Safety: An adult should assist when using hot glue.**



10. Use the thumb tack to make a hole in the center of the front of the car (between the poster board or cardstock's edge and the straw). Bend and place a paper clip through the hole to act like a hook on the car.
11. Tie a 12-inch piece of string to the paper clip.
12. Place the car at one end of the round road and use the string to pull the car along the road. Explore how the car with square wheels moves smoothly along the road!



STEM Explanation:

The square-wheel car displays geometry, the mathematical study of shapes, in a fun way. First, lets explain how round wheels on flat roads work! Wheels used on cars and bikes are constructed to follow the principles of a circle, where the distance from the center of the wheel to the edge, or the radius, is the same all the way around. Therefore, the round wheels keep the vehicle at an equal, balanced height as it rolls along a flat road. If there were square wheels on a flat road, then the elevation of the vehicle would constantly change because the edges of the square are not all equidistant from its center. This would cause the car to be at a low point when the flat edge is on the road, but at a high point when the square wheels roll to their pointed corners. The solution is an uneven road! A road made of a series of curves would allow square wheels to roll across smoothly at an even height. A special curve called a catenary curve would be measured to have a diameter that matches the size of the square wheels. These matching measurements are important because they would keep the center of the square wheels balanced and keep the vehicle steady for a smooth ride.

Catenary curves are strong shapes that can support themselves, and they can be found all around, from skateboarding half-pipes to archways such as the Gateway Arch in St. Louis!

Check out the geometry below that derives the equation that was used to calculate the curve to square wheel size ratio:

$$\cos 45 = \frac{AC}{AB}, \text{ or } AB = \frac{AC}{\cos 45} = \frac{r}{\cos 45}$$

$$AD = r$$

$$DB = AB - AD = \frac{r}{\cos 45} - r = r\left(\frac{1}{\cos 45} - 1\right) = r\left(\frac{1}{.71} - 1\right) = r(1.41-1) = 0.41r$$

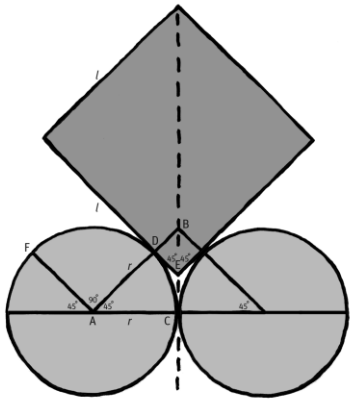
$$l = \widehat{DF} + 2DE$$

$$\widehat{DF} = \frac{2\pi r}{4}$$

$$DE = DB = 0.41r$$

$$l = \frac{2\pi r}{4} + 2 \times 0.41r = 0.5 \times 3.14r + 0.82r = 1.57r + 0.82r = 2.4r$$

$$r = \frac{d}{2}, \therefore\ l = 2.4 \times \frac{d}{2} = 1.2d$$



https://www.exploratorium.edu/snacks/square-wheels

Career Connection:

Geometrists study the size, shape, and position of two-dimensional shapes and three-dimensional figures. They use the measurement, properties, and relationships of angles, surfaces, and solids to develop theories and patterns about our world. They apply their findings and geometric reasonings to architecture, art, engineering, robotics, astronomy, sports, nature, and more.

Resources:

https://www.exploratorium.edu/snacks/square-wheels
https://my.vanderbilt.edu/stacyfonstad/files/2011/10/squareWheels.pdf
https://math.stackexchange.com/questions/1006293/is-the-square-wheeled-tricycle-at-momath-stable