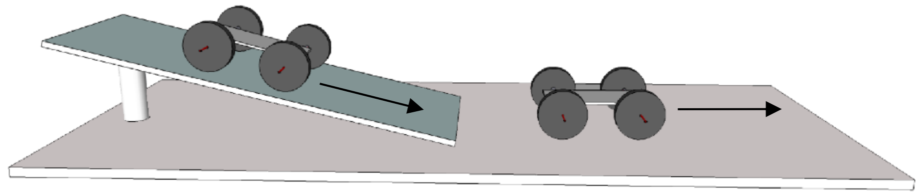
CAR ON A ROLL

Car model for motion-based activities



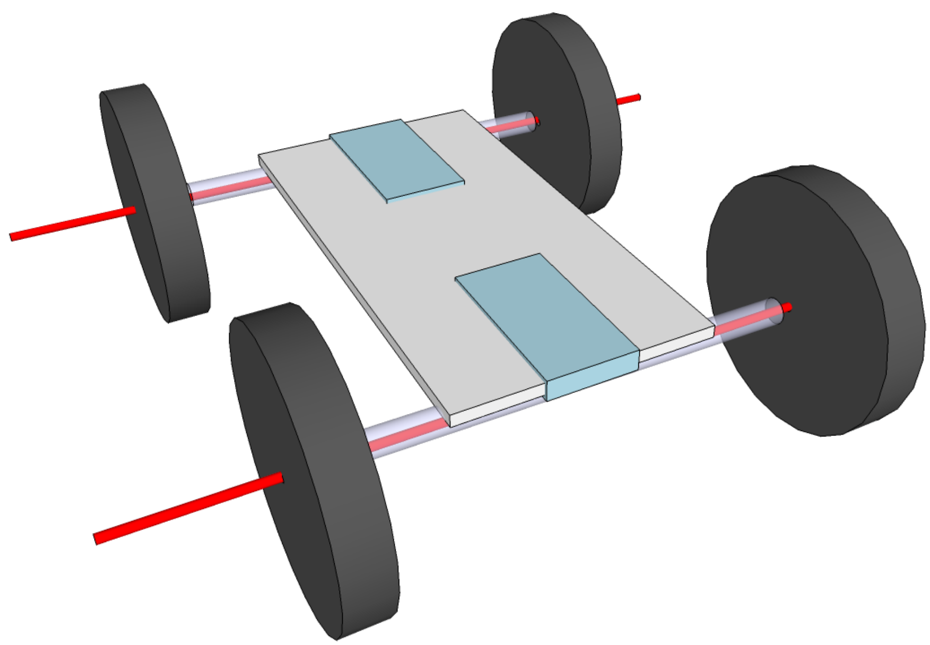
Curriculum topics:

- Motion
- Momentum
- Friction
- Simple Machines
- Kinematics
- Conservation of Energy

Subject(s):
Physical Science
Engineering

Grade range: K – 12

Model cars teach students about motion along inclined planes, friction, gravity, momentum, and potential vs. kinetic energy. The models do not need to be complex in design. These model cars consist of a simple chassis and a straw-based axle system (simple machine) that produces minimal friction and allows the cars to roll with little energy input, making them ideal learning tools for students of all ages.



Who we are:

Resource Area for Teaching (RAFT) helps educators transform the learning experience by inspiring joy through hands-on learning.

For more ideas visit
https://raft.net/resources-2/

Materials required

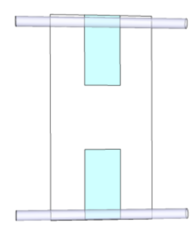
- Corrugated plastic sheet or cardboard (x1)
- Plastic coffee stirrers (x2)
- Clear plastic straws (x2)
- Foam disks (x4)
- Adhesive labels (x2)
- <u>Not included:</u> Cardboard, binder covers, books, or other materials for make a ramp
- Optional: Binder clips or similar weights to investigate effects of changing car mass
- Optional: Fabric sheets, sandpaper, or rubber to explore changes in surface friction

Design Challenge

Challenge learners by having them build the cars without instruction (or just show the completed car on the title page). They may already have an idea of how to make cars with turning axles. Encourage them to play with the materials and see if any unique ideas come to mind. For example, one might build a car with more than two axles or more than two wheels per axle. One or more learners might see that there are several ways of making a car that rolls. This can encourage them to build cars in a similar fashion or create their own designs together. This helps learners experience and practice collaboration skills necessary for success in the real world.

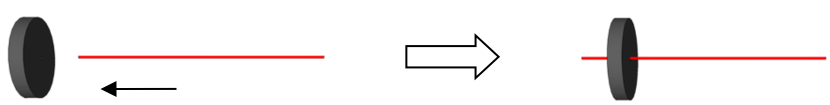
Set-Up

Tips: *Use a ramp to observe downhill motion of the car models. Have students set up simple ramps before building the car models. Younger students may need some adult assistance with assembly.*

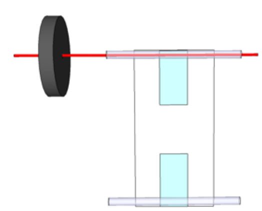


1 Secure the clear straws on each end of the car body (plastic rectangular sheet or cardboard) centered across the width using adhesive label or tape, as shown.

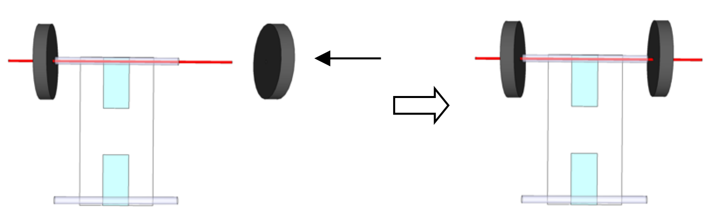
2 Insert one end of a coffee stirrer through the hole in one of the foam disks until 1” of the stirrer sticks out from the other side of the disk, as shown below.



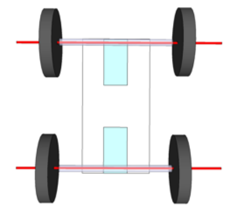
3 Insert the other end of the coffee stirrer through one of the clear straws secured to the car body (shown at right).



4 Slip another foam disk onto the coffee stirrer, as shown below.



5 Repeat steps 1-4 for the other end of the car. Roll the car on a flat surface to ensure the disk wheels turn freely.



To do and notice

> *Tip: If the foam disks slip and move along the coffee stirrers, attach small paper clips or similar items to the coffee stirrer ends to prevent the disks from falling off.*

1 Mark a starting line on a flat surface. From the starting line, roll the car across the surface and note the distance traveled.

2 Position a ramp (inclined plane) so that its base is at the starting line. Roll the car down the ramp and note the distance traveled from the starting line. Did the car travel farther from the starting line than before? Why or why not?

3 Cover the ramp with different materials to explore surface friction. For each material, roll the car down the ramp as in step 2, noting the distance traveled from the starting line. Based on observations, which material produced the most surface friction?

4 Attach binder clips, paperclips, or other items to the car to change its mass. Roll the car down the ramp as in step 2. How does changing the mass of the car affect its momentum and velocity?

5 Adjust the ramp height (incline angle) and repeat steps 1-4. Compare new observations with previous observations. Discuss with a partner and explain any differences you noticed.

Learning for multiple grade levels
When using this activity with elementary learners, explain the rolling in terms of simple pushes and pulls (forces) and the relative strengths of the pushes/pulls. Discuss how forces change an object's position over time and that this can be measured (example: miles/hour west). Learners can think about how the wheel and axle are simple machines that make moving an object easier. For middle school and high school learners, they can think about the car's motion in terms of unbalanced forces causing changes in an object's velocity (Newton's Laws of Motion) or explore force vectors by measuring the car's mass, velocity, distance traveled, and ramp incline angle. Additional materials can be added to investigate momentum and work.

Content Standards:

NGSS

Forces & Motion:
K-PS2-1
K-PS2-2
3-PS2-1
3-PS2-2
MS-PS2-2
HS-PS2-1

Kinetic and Potential Energy:
4-PS3-1
MS-PS3-2
MS-PS3-5

Gravity:
5-PS2-1

Compare and optimize multiple solutions:
K-2-ETS1-3
3-5-ETS1-2
MS-ETS1-2
MS-ETS1-4

Learn more

- Investigate the minimum ramp angle required to start the car in motion down the ramp
- Determine the type of ramp surface covering that produces the most friction
- Add hard or soft bumpers to explore conservation of momentum during collisions. How far does the car bounce back after hitting a wall?
- Conduct an experiment to find the optimum mass to be added to the car in order to roll down one ramp and reach the top of an adjacent ramp.
- Create a sail and determine the maximum distance the car will travel on a flat surface using the wind from a small fan to move the car.
- Design a method to cause the car to turn in a specific direction, perhaps to follow a short track.
- Use kinematic equations to calculate the time for the car to reach the end of the ramp and then test to compare experimental vs. calculated value (see *Science Behind the Activity*)

Visit **https://raft.net/resources-2/** to view the following related activities!

Cart the Box
Fender Bender Box Cars
Retractor Car
Rollback Can
Roller Racer
Craft Stick Catapults
Staple Remover Catapult
Puff Rocket
Stomp Rocket

Resources

See these websites for more information on the following topics:

- **Newton's Laws** – http://www.physicsclassroom.com/Class/newtlaws/
- **Videos on Balanced and unbalanced forces from the Khan Academy** – https://www.khanacademy.org/science/physics/forces-newtons-laws/balanced-unbalanced-forces/v/balanced-and-unbalanced-forces

The science behind the activity

The wheel and axle is one of the six simple machines. Machines make work easier by changing either the size and/or the direction of an input force. A wheel and axle combination consists of two circular objects of different sizes, with the larger wheel turning around the smaller axle. The friction between the wheels and the surface below, plus the friction of the axle rubbing in the axle supports, slows the car. For each rotation, the axle travels a shorter distance around than the wheel. The shorter turning distance and smaller diameter of the axle means less energy is lost as the car moves.

Newton's 2nd Law of Motion, in its simplest form, states that an object acted upon by a net force accelerates. In symbols this is written $\mathbf{F_{net}} = \mathbf{ma}$. This means that the sum of all forces acting on the object will lead to a net acceleration, which could be zero if the acting forces all oppose one another with equal magnitude. If the car is placed on a flat surface that is parallel to the ground, the car will not move on its own because the net force on the car is zero. Newton's 3rd Law of motion says that for every force acting on an object there is an equal and opposite force also being applied. Gravity pulls downward on the car and in response to this force the surface applies an upward force on the car called the normal force (F_N). The strength, or magnitude, of the normal force is equal to the force of gravity acting on the car and since the two forces act in opposing directions they cancel each other out. If a car is at rest on a flat surface and no horizontal force is applied, the car will remain at rest (Newton's 1st Law). If a horizontal force is applied to the front or rear of the car, it will roll. The Friction Force ($\mathbf{F_{fr}}$) will act in the opposite direction and slow the rolling car down.

Applying a horizontal force to the car will cause the car to roll in the direction of the applied force. The friction force described above ($\mathbf{F_{fr}}$) will act opposite the direction of the applied force and slow the car down. The distance required to stop the car will depend on the magnitude of the applied force. In other words, the harder the car is pushed, the farther it will travel but it will eventually stop. Forces, being vector quantities, have both magnitude and direction. Vectors can be divided into components (x and y) that point along axes in a Cartesian coordinate system. When the car begins rolling down an inclined plane (ramp), it is the component of gravity pointing along the incline ($\mathbf{Fg_x}$) that causes the motion of the car (see below). The magnitude of this component will depend on the angle of incline.

According to Newton's 2nd Law, $\mathbf{F_{net}}$ is the sum of all forces acting on the car. Notice in Figure 7 that $\mathbf{F_N}$ and $\mathbf{Fg_y}$ are equal and opposite (Newton's 3rd Law) and thus cancel out of the equation. Notice also that $\mathbf{Fg_x}$ and $\mathbf{F_{fr}}$ do not cancel each other out because they are not equal in strength, symbolized by the difference in length of the arrows in the diagram. The axle design minimizes the energy lost due to friction, meaning that the effect of the friction force $\mathbf{F_{fr}}$ is negligible and can be ignored when applying the 2nd Law or kinematics to mathematically describe the motion of the car down the incline. In most cases this produces a close approximation of the net force for this system. The effect of friction can be made greater by covering the ramp surface with materials that increase the surface friction of the ramp and if the materials are added to the system, friction should be included in the $\mathbf{F_{net}}$ equation. Friction should also be included in the equation when the car is rolling on a flat surface parallel to the ground because it is the reason the car slows down and stops.

$$F_{net} = ma = (F_N - Fg_y) + (Fg_x - F_{fr}) \qquad \text{[Note: } F_N - Fg_y = 0\text{]}$$
$$F_{net} = ma = (Fg_x - F_{fr})$$
$$F_{net} = ma \approx Fg_x \qquad \text{if } F_{fr} \approx 0$$

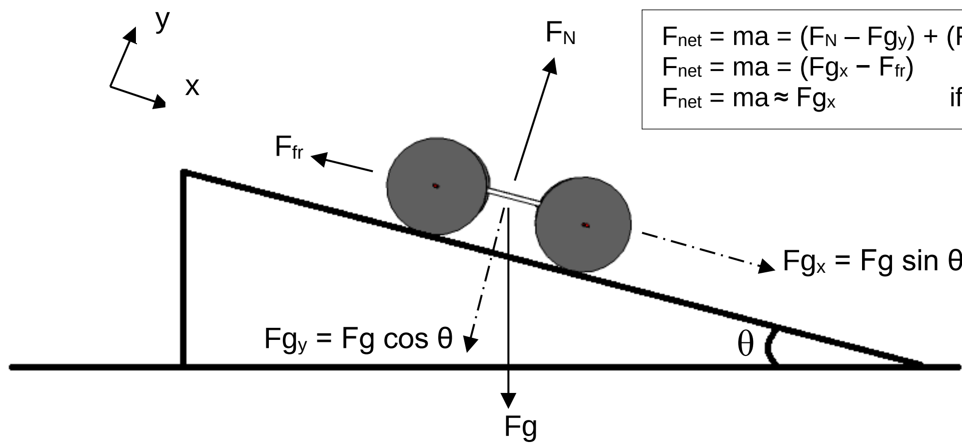


Figure 7