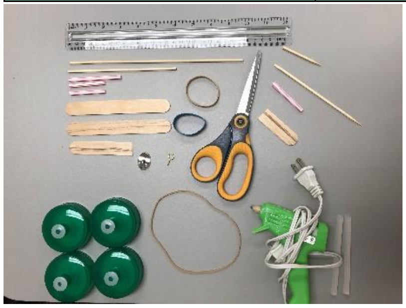
KINETIC CARS
LESSON

DRIVING QUESTION: HOW CAN WE BUILD ENERGY EFFICIENT CARS?

Recommended Grades: K – 8; Adaptations and resources are available for 9 – 12.

Classroom or Center Activities	*Outside or Larger Space Activities*	*Technology-Based Activities*	*Stem-to-Go Take Home*	*Field Work and/or Natural Area Needed*
X	X	X	X	



Materials: Measuring tape. Various building materials can be used for the cars, but we suggest: 1 plastic straw cut into (1) 3 inch section, and (2) 1.5 inch sections, 4 water bottle lids with built in sports button cap, 2 bamboo shish kabob skewers that are trimmed so that one is 10 inches and the other is 6 inches in length, 3 Popsicle sticks (one of which should have 1 inch cut off the end), adhesive hook, eyelet picture hanger, glue gun, two wide rubber bands, and one medium width rubber band.

Teacher Prep: <10 Minutes
Participant Activity: 30 minutes to 1.5 hours
Objectives:

1. Explain the difference between potential and kinetic energy. (K-8)
2. Identify, build, and use simple machines: Wheel and axle, pulley, levers, wedge, screw, inclined plane. (K-8)
3. Measure, calculate and graph distances, mass, acceleration, and force. (5-8)
4. Apply Newton's Laws of Motion. (K-8)
5. Evaluate and improve design. (K-8)

STEM Skills

S: Apply Newton's Laws

T: Classify Simple Machines

E: Build, test, and evaluate machine performance

M: Calculate, graph, and evaluate design efficiency.

Teacher Tips

Plan ahead: Ask for donated scrap materials ahead of time. Sports drinks bottle caps work the best for wheels, which is the trickiest part. If you use plain bottle caps, you will need to pre-drill the holes. Note: The Scrap Exchange in Durham, NC has sports bottle lids by the box for $8.

Total prep: < 20 minutes for copies and materials

Safety: Risk factors may be: UFO's (Unintentional Flying Objects, like rubber bands), slips/falls due to objects on the floor, cuts due to scissors, and burns from hot glue. Use tweezers and Popsicle sticks to press things together.

Sensory Integration Issues: This tends to be a noisy activity that requires space to spread out while building and space to race. For participants with fine motor skill issues, provide assistance with hot glue.

Cost: Minimal. The cars can be made from recycled materials, or sports bottle lids can be purchased.

What else do I need? Hot glue guns and duct tape, possibly a box cutter or heavy duty shears, depending on the age of the participants. A kitchen scale is handy for measuring the mass of cars.

Clean Up: Allow extra time. Glue is messy

Kinetic Cars Lesson Plan

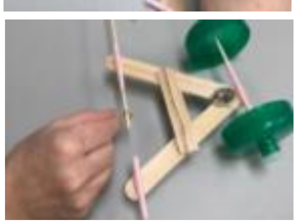
1. Print it out: Several handouts can be used in centers to get started. This lesson utilizes two introductory physics components: Simple Machines and Newton's Laws of Motion. These underlying physics concepts can help participants to problem-solve and make informed choices in modifying designs, and may make the perseverance aspect of engineering more fun.
    a. Cartoon Physics Laws: There are many versions on the web. Here's the one we used: http://www.dgp.toronto.edu/~karan/courses/csc2529/cartoonlaw.htmrk
    b. Kinetic Cars Test Drive
    c. STEM-TO-GO Simple Machines in My Life
2. Activate prior knowledge: There are several options to engage learners using art, hands on activities, and a home scavenger hunt.
    a. Use Cartoon Physics to prompt participants – How is the cartoon character breaking physics laws? Tom and Jerry or Roadrunner/Coyote cartoons work well for this. Then, participants can use the three Newton's laws to draw simple cartoons that are violating the laws.
    b. The STEM-TO-GO Simple Machines in My Life scavenger hunt can be used either as an initial or summative/assessment activity.
    c. To set up centers based around simple machines, Lesson 3 of Rube Goldberg's Incredible Machine Lesson Plan is effective. https://media.rubegoldberg.com/site/wp-content/uploads/2017/10/Rube-Goldberg-Lesson-Plans.pdf"
3. Procedure: Depending your participants, you may either provide direct instruction with step-by-step directions to build a specific car, or simply set out the materials and let them work through it as an inquiry. Here are the directions for how we made our prototype.

a. Build the frame using Popsicle sticks. Use the two regular size sticks to form the frame of the letter A, with the short stick as the cross bar. Overlap and hot glue the two sticks at the A point to make it sturdy. Then, glue the shorter Popsicle stick as the cross bar.

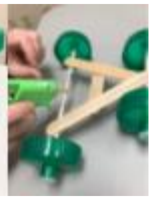
b. Mount the straws to run the axle through. On the top of the A, place the longer straw segment parallel to the bracing Popsicle stick. Test your positioning by sliding the axle/skewer through the straw to ensure that the straw is straight across so that the car will travel in a straight line. On the bottom of the A, place two sections of straw to fit along the chassis or frame of the bottom of the car. Either hot glue or duct tape can keep it attached. Make sure you slide the axle into the straws so that the axle will turn inside the straw and connect all the way across.

c. Mount the rubber band engine. On the point of the A frame of the car, just beneath the straw for the front wheel and axle, glue the hook so that a rubber band would hang towards the rear axle. Select a bamboo skewer. Measure the desired width of the wheel and axle. The front skewer for the axle should be about 6 inches, and the skewer used the rear axle should be about 10 inches. The axle should extend beyond the frame and width of the both wheels. It is critical that the wheels remain fixed in place on the axle.

d. Assemble the left wheels. Start with the front wheel. Close the cap to the lid. Fill it with hot glue. Push the 6 inch skewer into the hot glue and twist it gently once. Hold and press the axle so it is perpendicular to the wheel. Assemble the left rear wheel by using the same process with the 6 inch skewer.



i. Attach the right front wheel. Turn the car sideways so that the assembled wheel is on the ground, then slide the axle through the straw. Add the second front wheel using hot glue, and flip it so that the glue doesn't connect to the straw on the frame. Make sure that the straw remains fixed, but that the axle will spin inside the straws.

e. Attach right rear wheel: Turn the car sideways so that the assembled left wheel is flat against the table, then slide the axle through the left straw. Add the eyelet hook onto the middle of the axle, then thread the axle through the right straw. Fill the right tire with hot glue and push the assembled axle into it, making sure that the straw does not touch the hot glue inside the wheel. After the glue cools/dries in the wheel, turn the car right side up and move the eyelet hook into the middle of the rear axle. Secure the hook with a layer of glue so that that it no longer spins freely around the axle and the screw part is hanging down to catch the rubber band engine.

f. Add the wide rubber bands to the rear wheels. These will provide grip to allow the wheels to have friction to move forward.

g. Push Test: Push the car forward and adjust the wheels to make sure the car travels straight and that all the wheels turn. If the car will not move correctly, just peel off any problem glue and try again.

h. String the engine: Place one end of the rubber band loop from the bottom then around the back towards the front of the engine. Pull the rubber band through itself so that it is attached to the axle. Make sure that the rear axle's rubber band loop catches onto the screw sticking out from the eyelet. Take the other end and hook it to front hook.

i. Start the engine: Make sure that the rear axle's rubber band loop catches onto the screw sticking out from the eyelet. Turn the rear wheel counter clockwise to wind it up. Hold the axle. Then set it down on a flat, smooth surface. The car should move forward in a straight line.

4. Data Collection: Using the data sheet, measure how far the cars move. Identify any issues and engineering modifications.
5. Collaboration: Although participants may want to work independently, when they work in teams, it is easier to trouble shoot and to help each other solve engineering/design problems. Perseverance and applying Newtonian Laws can help teams and individuals streamline their design and improvements.

Car version	Moves forward and straight? Yes or No	Distance moved	Comments	Physics Issue and Modifications Needed Ex. Too heavy, wheels won't spin, or wheels spin out, friction, resistance, unbalanced and goes only one direction, material failure (glue came off)	Newton's Laws Write Down 1 2 or 3
1					
2					
3					
Ramp Test (optional) use an inclined plane or ramp					
Mass Test (optional) Use a postal scale to see how changing the weight (mass) impacts the distance traveled.					

6. Data Analysis: It is a really good idea to encourage a minimum of three "generations" or "model years."

Each year, car manufacturers update and improve their model. They work out the "kinks" or design flaws and try to make the car more appealing to buyers. For example, a 1990 Honda Civic SI looks very different from a 2019 Honda Civic SI. It took many years' worth of design changes to evolve.

Images from:
1990: https://static.cargurus.com/images/site/2010/03/04/10/08/1990_honda_civic_2_dr_si_hatchback-pic-98795920132339838-1600x1200.jpeg

2019:https://www.google.com/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiHwvu08J3hAhVLMqwKHTagBXkQjhx6BAgBEAM&url=https%3A%2F%2Fwww.kirklandhonda.com%2Finventory%2Fnew-2019-honda-civic-si-coupe-base-fwd-2dr-car-2hgfc3a58kh751117&psig=AOvVaw39DijU9HTlrstWzl1p6Ahv&ust=1553623363076450

In this case, a bar graph would be a great tool for participants to see their progress as they work out their own flaws or kinks in their design models. What is their goal? If their goal is to go farther, how does the mass of the car affect how far it travels? Would it be better for an economy car to be lighter or heavier to be more fuel efficient? How does the sturdiness impact safety?

7. Resources and Adaptation for K – 1st graders: In this age group, hot glue is likely problematic. It might be better to utilize Matchbox/Hot Wheels cars and measure their traveling distances. This age group would enjoy building ramps to investigate how ramp angles and length affects distance traveled by cars. This also can be a good opportunity to introduce the term "independent variable" for height of the ramp and "dependent variable" for how far the car travels. The "control", which is what you keep the same to compare against, would be using the same car at the two heights.

8. Resources and Adaptation for 1 – 3rd graders. Again, hot glue can be tricky with young children. It may be easier to use pre-made wheels and axles and use duct tape to make the frame of the car. To make this activity more fun, cut a cardboard toilet paper tube into thirds and tape it onto the cross bar in the frame of the car. Measure the mass of carrying different objects and graph the mass of the car with the load versus the empty car. Graph the difference. If you add a ramp into the mix, then participants can see that the heavier car will go further after it travels down an incline, which demonstrates Newton's laws. It also ties in well with road signs in the mountains with escape ramps for trucks who might accidentally lose their brakes as they go down the mountains.
9. Resources and Adaptation for 5 – 8th graders: In this age group, structured collaboration may be helpful.
   a. Divide participants into groups of three. Although participants should be working together, it may be helpful to have a #1, #2, and #3 to alternate the role of "lead engineer" for the model year. Participant teams may also enjoy naming their model and team.
   b. For 7th and 8th graders, try using an analogy of a pit crew from racing teams, and add a time pressure element using a timer to complete the build. Try using a timer for Trial 1: 20 minutes, Trial 2: 15 minutes, and Trial 3: 5 minutes. If you have enough room, they could race one another on the last heat.
10. Resources for and adaptations for 9th– 12th graders: Try the Mousetrap Car Challenge. Participants apply what they know about natural laws and potential/kinetic energy to build a more sophisticated car. https://mesa.ucop.edu/wp-content/uploads/intranet/MESA_Day/Curriculum/high_school/mousetrap/cu_mousetrap_car.pdf For 7 – 12th graders, the more in-depth lab links listed above have full experimental write ups that help participants process their observations.
11. Challenge/Inquiry option: Ask participants to build the car using scrap materials that you have on-hand, or ask that they bring in ahead of time, and provide them only with the same sized rubber band as the power source for their car. Ask them to sketch their design plan ahead of time with their team, then bring in or gather their own materials for building.

12. Conclusion: Regardless of construction or design materials, participants' graphs are likely to demonstrate that that working on a design helps improve the performance. How might car manufacturers take into account mass of a car when looking for performance? For fuel economy? For safety? If participants were in the market to buy a brand new type of car, would they buy the first model year or wait a year for the second model?
13. English/Language Arts Extension: For Middle to High School age participants, this article explains the demise of muscle cars. https://musclecars.howstuffworks.com/muscle-car-information/how-muscle-cars-work7.htm
    a. What is a muscle car? What happens when fuel prices go up?
    b. Here is an opinion piece that is packed with graphs. How have SUV's fared in recent economic times. https://www.bloomberg.com/opinion/articles/2018-05-17/american-appetites-for-suvs-pickups-might-not-doom-fuel-economy
    c. For Middle and High School participants: What is the difference between a muscle car and a sports car? Make a Venn Diagram to compare/contrast. How is the auto industry changing to meet its customers' preferences? Here's an opinion piece that would also give some participants a good opportunity to agree/disagree and cite reasons in a potentially lively debate. It is also a good opportunity to point out bias in an article and persuasive writing. https://www.businessinsider.com/the-muscle-car-is-over-2015-5
    d. For teen participants: Many teens already may be thinking about driving. Ask "What if…?", and "What about YOU?" questions. What do YOU think is going to happen to fuel prices? How do you think fuel economy and greenhouse gas emissions may impact car manufacturers? How do hybrids and electric cars factor into decision making? Finally, if money was no object for the purchase of a new car, what kind of car would you buy? Ask participants to post pictures of participants' "dream cars." Then allow participants an opportunity to vote for the one they would want to buy. Consumer Reports Magazine has an annual car review edition that is a good resource for their decision-making.
    e. Public transportation and car ownership and using the web to plan a trip: How available is public transportation in your community? In some towns, like Chapel Hill, NC, there is a free bus system for anyone. Other cities and towns may have hard to navigate or, like many rural areas, have minimum public transportation available. Which is more cost-effective for your community - owning a car or using public transportation? Where is the closest public transportation available to your program site? Ask participants to plan a trip using trains or buses and calculate the cost of the trip. How does this compare with the cost of owning and using their own car? How much does an UBER cost versus a public bus for the same distance? Here is a link to Durham's public transportation app. https://godurhamtransit.org/trip-planner

Resources utilized for the development of the Kinetic Cars Lesson

- https://www.youtube.com/watch?v=SC7Nbn1W6sY
- https://4-h.org/parents/stem-agriculture/youth-stem-activities/rubber-band-cars/
- https://www.youtube.com/watch?v=hjXYVpAyYG0
- https://www.scientificamerican.com/article/build-a-rubber-band-powered-car/
- https://4-h.org/parents/stem-agriculture/youth-stem-activities/rubber-band-cars/
- https://media.rubegoldberg.com/site/wp-content/uploads/2017/10/Rube-Goldberg-Lesson-Plans.pdf
- https://www.youtube.com/watch?v=JVUaU-NXLSA
- https://www.youtube.com/watch?v=JVUaU-NXLSAhttps://www.quia.com/pop/36483.html?AP_rand=1020393551
- https://www.youtube.com/watch?v=9xhEXDrMMLg
- https://www.grc.nasa.gov/www/k-12/airplane/newton.html
- http://www.rahul.net/figmo/Archives/toon-physics.html

- http://www.dgp.toronto.edu/~karan/courses/csc2529/cartoonlaw.htmrk
- *http://www.justscience.in/wp-content/uploads/2017/05/pjimage-1-2.jpg*
- http://www.troup.org/userfiles/929/My%20Files/Science/MS%20Science/8th%20Science/Force_Motion/simple_machines/bicycle_compound_machine.pdf?id=11340
- https://musclecars.howstuffworks.com/muscle-car-information/how-muscle-cars-work7.htm
- https://www.bloomberg.com/opinion/articles/2018-05-17/american-appetites-for-suvs-pickups-might-not-doom-fuel-economy
- https://www.businessinsider.com/the-muscle-car-is-over-2015-5
- https://godurhamtransit.org/trip-planner

NORTH CAROLINA NCCAP CENTER for AFTERSCHOOL PROGRAMS
Public School Forum of North Carolina

Kinetic Cars
Test Drive

Each year, car manufacturers update and improve their models. They work out the "kinks" or design flaws and try to make the car more appealing to buyers. For example, a 1990 Honda Civic SI looks very different from a 2019 Honda Civic SI. It took many years' worth of design changes to evolve into its most recent form.

1990

2019

Images from: 1990: https://static.cargurus.com/images/site/2010/03/04/10/08/1990_honda_civic_2_dr_si_hatchback-pic-98795920132339838-1600x1200.jpeg2019:https://www.google.com/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiHwvu08J3hAhVLMqwKHTagBXkQjhx6BAgBEAM&url=https%3A%2F%2Fwww.kirklandhonda.com%2Finventory%2Fnew-2019-honda-civic-si-coupe-base-fwd-2dr-car-2hgfc3a58kh751117&psig=AOvVaw39DijU9HTlrstWzl1p6Ahv&ust=1553623363076450

Track Your Changes

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Ramp Test (optional) Try an inclined plane or ramp						
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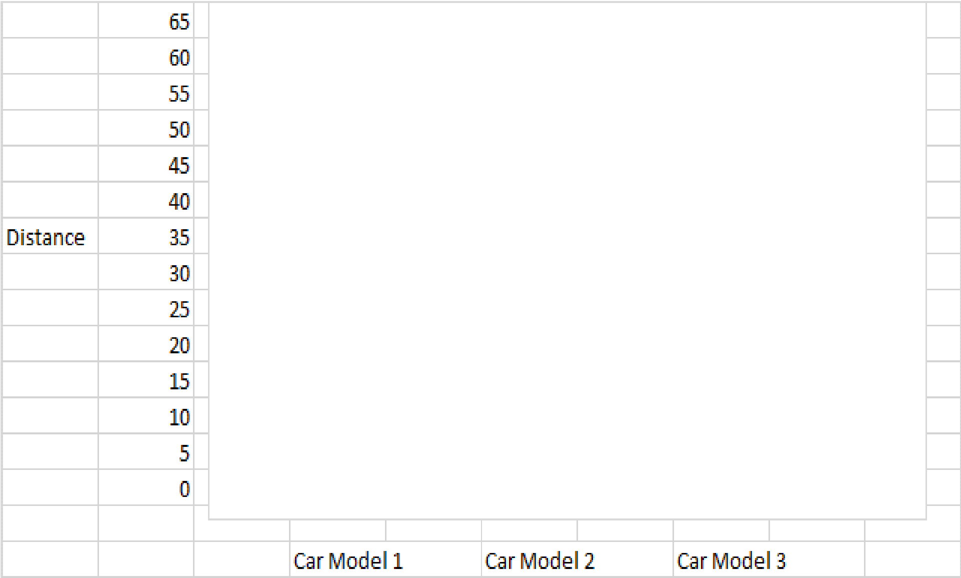
Graph It



Think about It

How did your car design change?

How can understanding physics improve your design?

Big Picture

How might car manufacturers take into account mass of a car when looking for performance? For fuel economy? For safety?

What about <u>YOU</u>?

What's your favorite/dream car?

Would you buy the first model year of a new type of car or would you wait a year to buy the second model? Why?

Kinetic Cars
Cartoon Laws and Newton's Laws

Draw a cartoon that follows the Cartoon Law of Physics. Does your 'toon also follow Newton's Laws of Motion?

Cartoon Laws of Physics

Adapted from: http://www.dgp.toronto.edu/~karan/courses/csc2529/cartoonlaw.htm

1. Toons can't fall until they notice that they should fall.
2. Toons that are moving will keep moving until they run into a solid object.
3. Scared toons that run through walls leave behind holes shaped like their bodies.
4. If a toon drops something, then the toon can run down twenty flights of steps before the object hits the ground. Then the toon will catch the object only to drop it anyway.
5. If a toon is terrified, it can go straight into the air. But if the toon is very scared, its feet may not touch the ground when it runs away.
6. If a toon moves fast enough, it will form a clone of itself.
7. Some toons can go through tunnel shaped paintings, but other toons cannot.
8. Cartoon cats can never be killed, but they can take the shape of a container.
9. All things fall faster than anvils.
10. All acts of revenge result in more acts of revenge.
11. Any toon that is poked with a needle will immediately defy gravity and shoot into the air.
12. Toons fall in slow motion gravity waves, one body part at a time, with only a stretched out arm and their hand left to wave goodbye.
13. Cool toons can make any object appear out of nowhere.
14. Explosions do not harm toons, they only make them ashy and smoky.
15. Explosives appear from nothing in toon space.

Newton's Laws of Motion

1st Law: Inertia: A body at rest stays at rest unless acted upon by an outside force. A body in motion stays in motion unless acted upon by an outside force.
2nd Law: Unbalanced Forces: Force = Mass Multiplied by Acceleration. F=M*A It takes force to move an object. The bigger the mass the more force it takes to move it or to stop it once it is moving.
3rd Law: Equal/Opposite: For every action, there is an equal and opposite reaction.

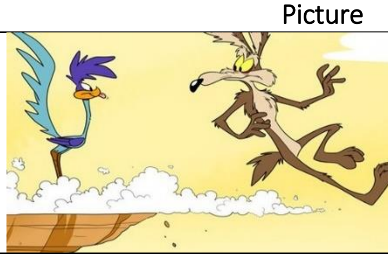
Cartoon Law	Picture	Newton's Law	Following Newton?
Toons can't fall until they notice that they should fall.		Inertia – 1st Law	Breaking it

Image taken from: https://cdn.vox-cdn.com/thumbor/urcDfLUngffe_uj1u_7MhAXgJRI=/0x0:458x344/1200x800/filters:focal(0x0:458x344)/cdn.vox-cdn.com/uploads/chorus_image/image/45826606/cliff.0.0.jpg