HESS

Clearing the Way with STEM

STEM Activities with the Hess Hauler Truck and Snow Plow

Gregory L. Vogt and Kaeson A. Mayer

Baylor College of Medicine

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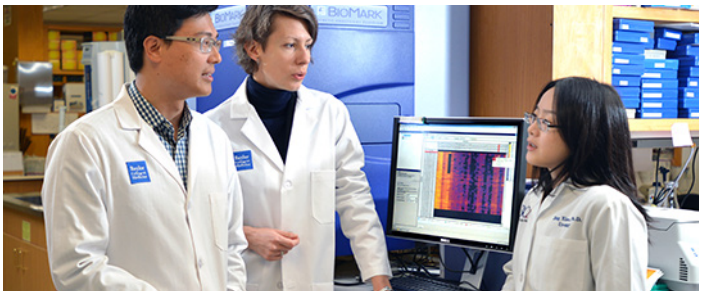
ORDER OF ACTIVITIES AND HESS TOY AVAILABILITY

- The order of the activities may be changed if it will create a more logical progression for the classroom.
- The 2026 Hess Hauler Truck and Snow Plow is available at www.hesstoytruck.com while supplies last.
- Activity guides for Hess trucks for years 2016 – 2026 are available on the Baylor College of Medicine Bioedonline.org website.

Baylor College of Medicine

Baylor College of Medicine (Baylor) is a health sciences university that creates knowledge and applies science and discoveries to further education, healthcare, and community service locally and globally. In addition to its School of Medicine, Baylor includes a Graduate School of Biomedical Sciences, School of Health Professions, and National School of Tropical Medicine.

Located in the heart of the Texas Medical Center, the world's largest health sciences complex, Baylor is surrounded by other leading healthcare and research institutions. This concentration of expertise has helped support the development of collaborations that advance every aspect of the college's mission.



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With nine affiliated teaching hospitals and partnerships with major institutions, including the University of Houston, Rice University, and NASA, Baylor has a diversity of resources unparalleled at other academic health centers. The college also partners with community leaders to serve Houston, Texas, and the world through outreach initiatives, innovative healthcare delivery models, and research focused on specific community needs. Its educational outreach programs reach students at all levels, from elementary school through college, creating a pipeline of learners interested in science and medicine.

Baylor is ranked by the National Institutes of Health at #2 in Texas and #23 in the nation among all medical schools based on NIH funding. Six departments rank in the top 10, including a ranking of #2 in genetics. Baylor College of Medicine is ranked in Tier One for research-intensive schools by U.S. News & World Report, along with 15 other medical schools.

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The Center for Educational Outreach at Baylor College of Medicine provides a wide range of educational programs and resources that help prepare and encourage students to pursue careers in medicine and the health sciences. Offerings include teacher professional development and curricular materials that improve the STEM content knowledge and skills of K–12 students. Educators can participate in professional development via the Center's face-to-face workshops or online courses, some of which are tailored to meet the needs and requirements of individual schools or school districts.

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BioEd Online℠ is a dynamic STEM teacher website that provides coursework, streaming video presentations, teaching slide sets, inquiry-based classroom activities, and complete teaching modules for grades Pre-K to 12. BioEd Online materials feature an integrated, hands-on approach to teaching STEM. Each inquiry-based unit is aligned with national and state science education standards.

Hess Toy Truck

Leon Hess-a builder, visionary, entrepreneur, patriot, and leader. And above all, a great father and family man. The remarkable qualities that made Leon Hess so special are at the heart of the Hess Toy Truck.

Born in Asbury Park, New Jersey, in 1914, company founder Leon Hess grew up during the Great Depression. In 1933, after finishing high school, and unable to afford college, the 19-year-old Leon Hess bought a secondhand 615-gallon oil delivery truck and started a business delivering fuel oil to homes in Asbury Park.

In 1964, just four years after opening the first of what would ultimately become more than 1,400 Hess-branded gas stations, Leon Hess decided to offer families a fun, high-quality, and affordable toy for the holidays as a goodwill gesture to customers. With that decision, he created a toy for kids of all ages—the Hess Toy Truck that has become a hallmark of the holiday season. Leon Hess insisted that the toys be made with outstanding craftsmanship, innovative electronics, and affordability, with batteries included—a standard that endures to this day.

For more than 60 years, the Hess Toy Truck has been one of America's most iconic and best-selling holiday toys. Generations of families have eagerly awaited each year's new design, with demand so high that the trucks often sell out within days of release.

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The Hess Toy Truck has earned national recognition as both a treasured collectible and a symbol of enduring quality and innovation. In 2024, the brand was named a finalist for induction into the National Toy Hall of Fame, reflecting its cultural impact and its place among the most beloved toys in American history.

Behind the joy of play lies real-world engineering. Each Hess Toy Truck can take years to design and includes working features, such as lights, sounds, ramps, ladders, pull-back motors, and aviation-inspired elements. Often with more than 300 precision-molded parts, every model embodies the science, technology, engineering, and math (STEM) principles that shape the world around us.

Since 2016, Hess Toy Truck has been a proud partner in STEM education, donating tens of thousands of toys to schools to accompany curriculum guides and inspire hands-on learning. Today, Hess Toy Trucks are used as learning instruments in classrooms, helping students connect the excitement of play with the foundations of science and engineering.

By linking the Hess Toy Truck to classroom learning, this STEM curriculum guide builds on an American holiday tradition to spark curiosity, imagination, and problem solving—making it an ideal tool for inspiring the next generation of STEM leaders.

Tools to Teach STEM

Hess Toy Trucks are much more than collectors' items. They are useful teaching tools that offer a variety of practical and fun ways to teach STEM subjects, such as force and motion, energy, and simple and complex machines. STEM is the acronym for science, technology, engineering, and mathematics. It refers to an integrated approach for developing many products and processes we depend on every day. STEM careers are also an important part of the current and future job market.

Activities in this guide use the 2026 Hess Hauler Truck and Snow Plow to explore possible solutions to winter weather problems across the United States. The large truck, called the hauler, transports the all-terrain snow plow in its rear-opening compartment. The snow plow has an attached plow blade and a pull-back spring motor to propel it in simulated snow-plowing operations.

The activities can be used sequentially as a complete unit or as individual activities inserted in an existing curriculum. While designed for grades 4–6, they can easily be adapted for higher or lower grades. Each activity has student instruction/data sheets that can be used for assessment and placed in student notebooks.

The Hess Hauler Truck and Snow Plow are both based on real vehicles in use across the country. The hauler is based on a classic garbage truck but with modifications to transport the snow plow. The rear door opens upward to reveal a large compartment in which the snow plow fits. To make storing or removing the plow easier, an inclined plane ramp can be deployed. The hauler can be used to support snow pushed up the ramp by the plow. This sometimes occurs when a snowstorm dumps huge amounts of snow and there is no place to pile it up along city streets. The hauler takes the excess snow to parks or vacant lots. Although a large plow blade is not part of the hauler, students can design, build, and test plows they construct and add to the hauler.

The snow plow is based on a single-rider, all-terrain vehicle with a plow blade in front. Vehicles like this are especially useful in rural areas where big trucks with plows are not available.

STEM CAREERS

Skilled workers for STEM fields are always in demand, with job openings exceeding the number of prepared candidates. In combination with the 2026 Hess Hauler Truck and Snow Plow, this guide provides powerful, stimulating learning experiences that relate to many STEM fields, such as those listed in "Select Careers" (right). These careers require a competency in science, technology, engineering, and mathematics.

SELECT CAREERS

- Architectural Engineering
- City Manager
- City Planner
- Computer Scientist
- Construction Engineering
- Manufacturing Engineer
- Mechanical Engineer
- Meteorologist
- Structural Engineer
- Traffic Engineer
- Transportation Dispatcher
- Transportation Engineer
- Transportation Maintenance
- Truck Driver

Created with Perplexity's AI image-generation tool using prompts and iterative design direction provided by Baylor College of Medicine (BCM).

01 Small Wheels, Big Wheels

Student teams design rear drive wheels to determine how the modification affects the snow plow's average travel distance.

Suggested Grades 3–8

With modifications for younger children

Suggested Grades **3–8**
With modifications for younger children

01 Small Wheels, Big Wheels

The Question

How does the diameter of the snow plow's drive wheels affect its driving range?

Where's the STEM

The four STEM domains—science, technology, engineering, and mathematics—are all at work in vehicles, whether they are small like the Hess Snow Plow or large like the Hess Hauler Truck. Force and motion, potential and kinetic energy, friction, and measurement are just a few of the STEM design processes at work.

In this investigation, student teams will measure the snow plow's driving range. Then, they will modify the plow's rear drive wheels by attaching larger corrugated cardboard wheels to see what effect the modification has on the plow's average travel distance.

Materials

PER INVESTIGATION TEAM

- Hess Snow Plow
- two 2-ply cardboard wheels, made from 3-layer construction (see note in Management Tips)
- "Wheel Diameter Investigation" student page

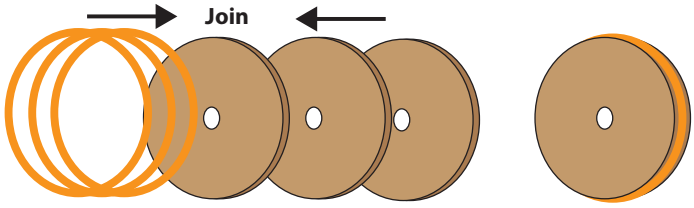
FOR THE CLASS

- Hess Hauler Truck
- ultra-low-temperature glue gun and glue sticks (see note in Management Tips)
- tape measure
- 20–30 ft. of string or rope
- painter's or masking tape for laying out the test course (see note in Management Tips)
- glue sticks
- 6 corrugated cardboard wheels for each Hess Snow Plow (see Management Tips for how to assemble the wheels)
- "Wheel Template Instructions" page
- 3 size 64 rubber bands for each wheel (see note in Management Tips)
- clear floor such as a hallway for testing the plows
- stopwatch or timing device

Management Tips

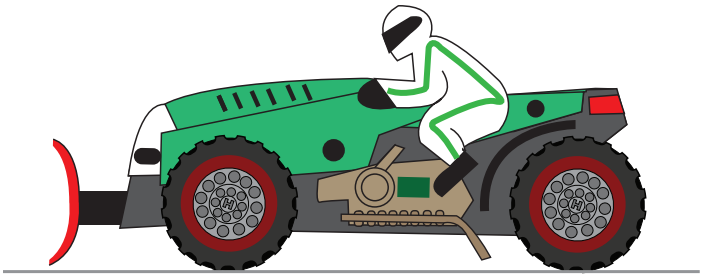
How to Make the Wheels

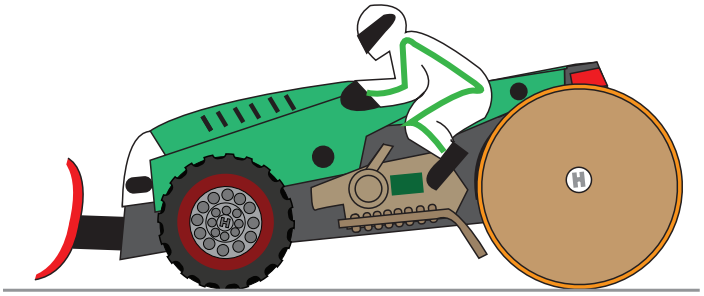
- The cardboard wheels need to be perfectly round, so it is best for the adult to make them for the teams.
- Cut out six paper patterns for the wheels. Use glue stick to attach each pattern to a piece of single-strength cardboard. Double-strength cardboard may be used instead but it is much harder to cut.
- The Hess Snow Plow will need one cardboard wheel (three circles) for each wheel.
- Carefully cut out the circles to make sure they are as near perfect as possible. Use the glue stick to join three circles together. This will make one wheel set.



Management Tips Continued

- Use a ballpoint pen to push through the center point of each wheel. The holes should be about 3/8 inches in diameter and go straight through so you can look through them and see the H on the plow wheels, ensuring proper alignment with the rear wheel axles.
- Wrap three thick rubber bands around the rims of each wheel to increase road traction.
- Students will measure the range of the snow plow as it is first, then the adult will complete the following steps:
  - Attach the two wheels you made to the rear wheels of each team's plow.
  - Spread a bead of ultra-low-temperature hot glue on several points on the rear wheels of the plows. (This can be easily removed after the activity).
  - Press the cardboard wheels to the glue. Make sure they are centered on the plow wheels. (The snow plow wheels have a small H at their centers. When properly aligned, the H can be seen through the holes.)
  - When the glue has cooled, the plows are ready for test runs.
- **Note:** Unless the large wheels are perfectly round and perfectly aligned with the rear axles, the plow may curve off a straight-line path. If this occurs, measure the distance traveled by laying a string or rope along the path from start to finish. Then, measure the string or rope with the tape measure. Demonstrate how to do this for your students.





Test Area

- Designate a test area for comparing plow performance with standard plow wheels and the cardboard wheels. A smooth tile floor makes the best running surface.
- Use painter's tape to mark the starting line. Painter's tape is easier to remove than masking tape when the activity is finished.

Procedure

01 Introduce the activity by describing the Hess Hauler Truck. Focus on the truck's six wheels. Point out that the wheels are attached to axles that permit them to rotate. Wheels and axles are considered simple machines that enable vehicles to move.

02 The optimum size of a wheel is related to the size of the vehicle and engine. Hold up the hauler truck and the Hess Snow Plow and point out the size difference of each vehicle's wheels. Ask, Why are they different? What effect might the size of the plow's wheels have on performance?

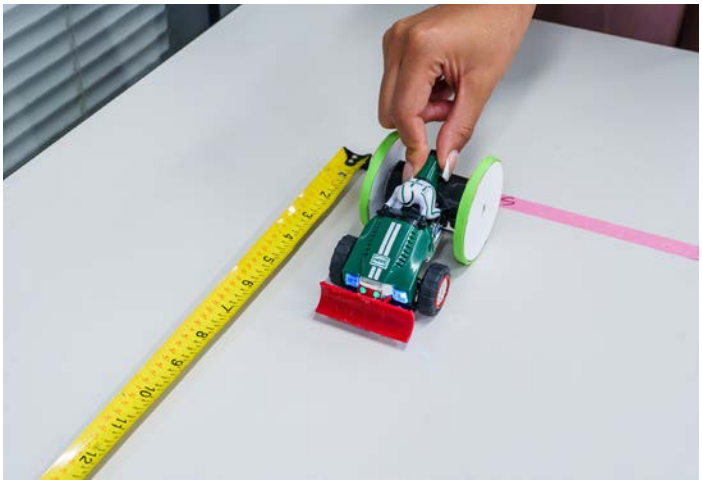
03 Distribute the student pages to the teams. Explain that they will conduct tests to determine how wheel size may affect performance on the plow.

04 Read over the instructions, data collection charts, and questions for activity wrap-up discussions.

05 Point out that students will begin by first determining both the distance traveled and how long it takes in seconds for the plow as is. Students may use the tape measure for distance traveled and a stopwatch or other timing device (such as a smartphone) to measure how long it takes.

06 Once students have the data for the plow, the prepared cardboard wheels can be attached to the rear drive wheels of the plow. It is best if the adult does the actual gluing to make sure the cardboard wheels are exactly centered on the plow's wheels. (Remember, they are aligned when you can see the "H" on the plow wheel through the holes on the cardboard wheels. Cardboard wheels that are improperly attached add a variable that turns the plow into a kind of clown car and makes comparisons of the different wheel size impossible.)

07 At the completion of the activity portion of this investigation, peel off the cardboard wheels from the plows. Any glue that sticks to the rubber tires can be picked off with fingernails. The cardboard wheels can be used again.



Wrap It Up

- Have students report on the results recorded on their student team pages.
- What was the average distance traveled, and how long did it take for the plow with its regular wheels, then with the cardboard wheels attached?
- **Note:** With the plow motor wound the same amount, both wheel sizes make the same number of rotations. One rotation of the 1-inch standard wheels propels the plow 3.14 inches. One rotation of the 2.5-inch cardboard wheels propels the plow 7.85 inches. The circumference of a circle equals its diameter multiplied by pi, or 3.14. Since the standard wheel is 1 inch in diameter, its circumference is 3.14 inches. The circumference of the 2 .5-inch wheel is 2.5 x 3.14, or 7.85 inches.
- What differences do you observe from the data? Which wheel size helps the plow to go the farthest? Which wheel size has the greatest average speed? How do you explain the differences? Possible variables include wheel circumferences, traction of the standard tires versus thin cardboard wheels, differences in the weight of the plows (the cardboard wheels add extra weight), how far the plow coasts when the potential energy of the spring motor is used up, and inertia of the two wheel versions.
- This investigation shows why wheel size is important to vehicle performance. The wrong size wheel will affect the speed and range of the vehicle. This is why the Hess Hauler Truck has larger wheels than the Hess Snow Plow.

Additional Activity

Use a smartphone timer or a stopwatch to determine the average speed of the plow without and with the cardboard wheels attached. To calculate average speed, divide the distance traveled by the number of seconds it takes the plow to travel from start to finish. For example, if the plow travels 30 feet in 6 seconds, its average speed is 5 feet per second.

Wheel Diameter Investigation

Team Members: _____ _____

_____ _____

Instructions:

1. Pick one team member as the driver. The driver activates the plow's spring motor by pulling the plow backward across the floor until the rear wheels click. The spring motor is now fully charged with potential energy.
2. Pick another team member to time how long, in seconds, it takes the plow to travel from the start until it stops. The timer calls out "Start," and the driver releases the plow.
3. Measure in inches how far the plow travels and how long it takes, in seconds, to stop. Repeat steps 1, 2, and 3 two more times.
4. Have your teacher attach the large cardboard wheels to the plow. When the glue has set, repeat steps 1, 2, and 3, and record the distance and time. (If the plow curves, use string to measure the path, as shown by your teacher.)
5. Add the three distances traveled for each wheel size. Divide the total by 3 to find the average distance. Do the same for the run times.

Small Wheels

	Distance	Time
Run 1		
Run 2		
Run 3		
Average		

Big Wheels

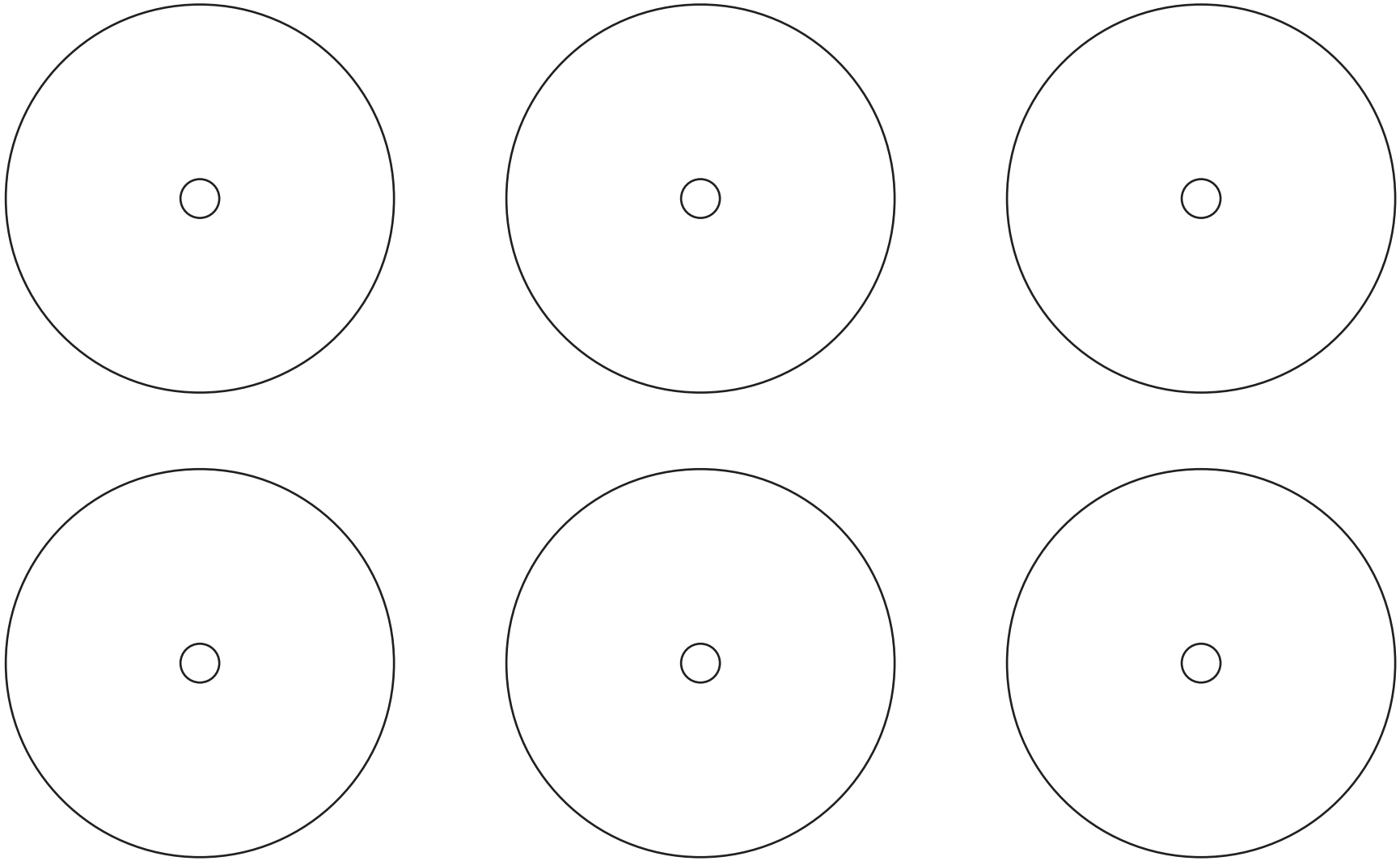
	Distance	Time
Run 1		
Run 2		
Run 3		
Average		

Answer the questions on the back of this page:

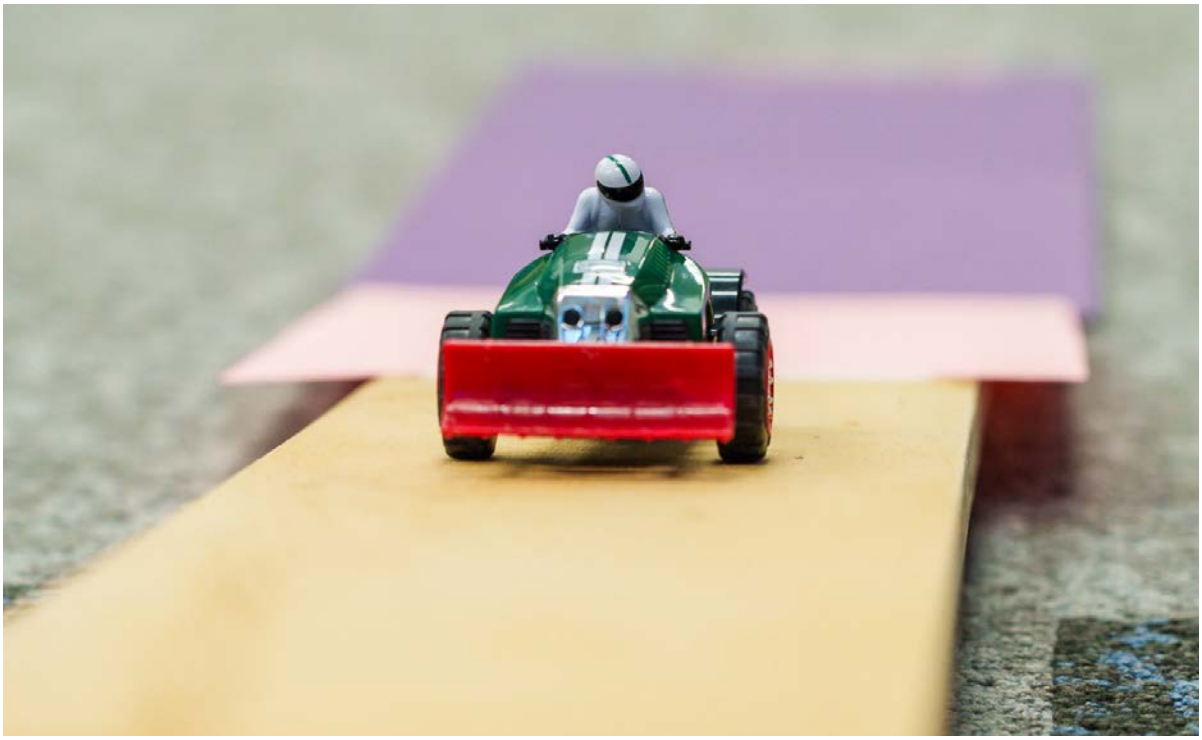
1. Which wheel size enabled the plow to travel the farthest? What might explain this?
2. Did the plow travel in a straight line? Why or why not?
3. What factors do you think affected plow performance (size, weight, traction, etc.)?
4. If you had to plow snow, which wheel size would you want?

Wheel Template Instructions:

1. Cut out each circle and glue the circles to single-ply cardboard using a glue stick.
2. Carefully cut out the cardboard around each wheel, keeping the edges as perfectly round as possible.
3. Use a ballpoint pen to punch out the center holes.
4. Glue, align, and stack three circles to make each wheel. Repeat to make two wheels.
5. Wrap the edges of each wheel with thick rubber bands for traction.



02 Road Surface Traction



Student teams prepare the snow plow for winter service by testing how well it performs on different road surfaces.

Suggested Grades 3–6

With modifications for younger children

Suggested Grades **3–6**
With modifications for younger children

02 Road Surface Traction

The Question

How does the type of road surface affect a vehicle's traction?

Where's the STEM

Every road is different—smooth and dry, concrete or asphalt, rough with dirt or gravel, or wet, icy, or covered in snow. Engineers design roads to provide enough traction for vehicles to travel safely in many different weather conditions. Without enough traction, vehicles can slide, skid, or lose control, making driving dangerous.

Traction is the grip between a vehicle's tires and the road surface. Good traction allows a vehicle to accelerate, stop, and turn safely. Poor traction makes it more difficult for tires to grip the road, increasing stopping distances and making it easier for vehicles to slide.

Traction depends on friction, the force that resists motion when two surfaces rub against each other. The amount of friction between a tire and the road changes depending on the type of surface. Rough surfaces, such as asphalt or concrete, generally provide more friction than smooth or slippery surfaces like ice or wet pavement.

Transportation engineers test different road materials in laboratories and in the field to understand how they affect vehicle performance. They measure stopping distances, tire grip, and vehicle control before selecting materials for highways, neighborhoods, and intersections. Using this information, they select road materials based on climate, traffic, and weather conditions. In areas that receive frequent snow and ice, they may also spread salt or sand on roads to increase traction and improve safety.

In this activity, teams will imagine they are preparing the Hess Snow Plow for winter service. The plow is new and the operators want to test it to see how well it performs. Teams will test the snow plow on different road surfaces.

Materials

PER INVESTIGATION TEAM

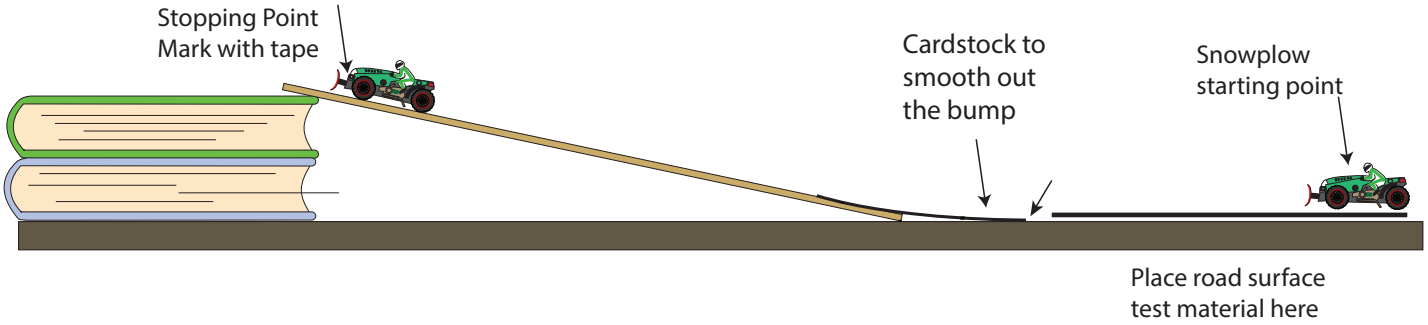
- Hess Snow Plow
- "Road Surface Traction" student page
- ruler or measuring tape

FOR THE CLASS

- cardboard or wood ramp, 4 feet (1.2 m) long × 6 inches (15 cm) wide
- books to support upper ramp end
- sandpaper
- wax paper
- aluminum foil
- cardstock paper
- carpet sample or door mat
- painter's tape or masking tape
- smooth floor surface

Management Tips

- The Hess Snow Plow is used for this investigation because it has a spring motor that powers the rear wheels, allowing traction to be tested. The Hess Hauler Truck does not have a spring motor and can only be propelled by gravity using a ramp or by an external push. Because the hauler's wheels are not powered, it cannot be used to test traction.
- Set up a ramp on a smooth floor surface. The teacher can set up one ramp for the class or allow students to set up their own ramps if using multiple trucks.
- Use a cardboard box or books to elevate one end of the ramp.



- Show teams that the ramp angle can be adjusted by adding or removing books to support the upper end of the ramp. Teams will have to find the best angle for the ramp so that the plow stops just before the upper end of the ramp. **Once properly adjusted, the ramp angle should be kept the same throughout the investigation**.
- Place a piece of cardstock paper at the bottom end of the ramp to smooth the transition between the ramp end and the road surface.
- Place a sample of road surface material (e.g., sandpaper) as shown in the graphic below to demonstrate where to place the different surfaces during testing.
- Use tape to mark where the back wheels will be placed so all plows are released from the same starting position—2 feet (~61 cm) from the lower end of the ramp.
- **Note:** All road surface materials should be 2 feet (~61 cm) long. You can join several sheets of sandpaper end to end by taping them together on the back.
- Teams should test each surface material three times and average the results. Measurements should be made from the lower end of the ramp to the front of the vehicle where it stops.
- A spray bottle of water can be used to simulate a rainy day by sprinkling water on a wax paper or aluminum foil surface.

Procedure

01 Ask students if they have ever been in a car that is skidding on a slippery surface. How did it feel? Was it scary?

02 Ask what caused the skid. Discuss the importance of tire traction with the road surface. How does traction change with different road surfaces and weather conditions (concrete, asphalt, gravel, dirt, rain, snow, ice)?

03 Show the test ramp and the materials for different simulated road surfaces.

04 Place the plow on the marked starting point 2 feet from the lower end of the ramp and release it. Show teams that the distance up the ramp can be changed by raising or lowering the upper end of the ramp. They will need to find the right angle that allows the plow to stop right before the upper end of the ramp. Tell them that once they determine the correct angle of the ramp, it cannot be changed.

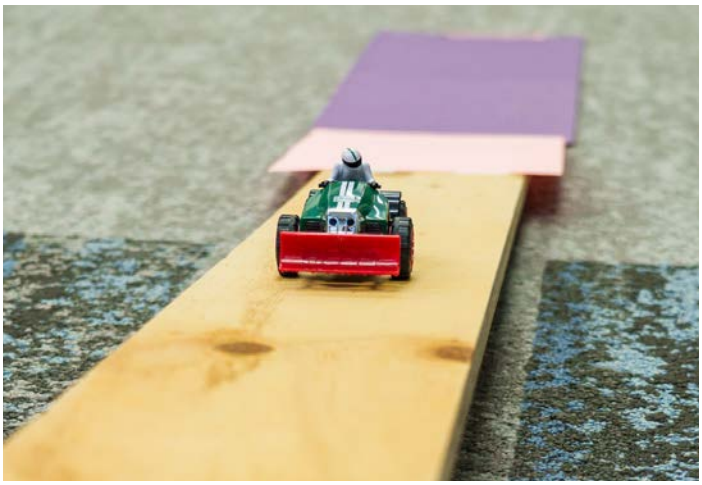
05 The smooth tile floor serves as the control for the investigation. During the tests, traction provided by the different road surface materials will be compared.

06 Point out the various road surface test materials and where to place them at the base of the ramp. Tell teams they will choose two different materials to test.

07 Hand out the student page and review with the teams.

Wrap It Up

- Ask teams to report on how each road surface they chose affected their results.
  - Why did the distances up the ramp change with different road surfaces? A shortened distance means that some of the plow's kinetic energy was lost as its drive wheels lost some traction while crossing the road surface.
  - What does it mean if the plow reaches the upper end of the ramp? The road surface used provided good traction.
- Explain that engineers carefully select road materials based on how much traction they provide. Roads with good traction help vehicles accelerate, stop, and turn safely, especially during rain and snow. Transportation engineers continue testing new materials to improve safety and reduce accidents.
- Discuss different ways drivers can improve their car's traction in winter conditions:
  - Get tires with deep treads for increased grip.
  - Sand or salt the road.
  - Use tire chains.
  - Add weights, such as sandbags, to the trunk to improve rear drive wheel traction.
  - Drive slower.



Additional Activity

Simulate wet road conditions by sprinkling water on an aluminum foil or wax paper surface. Observe how the wet surface affects the plow's traction.

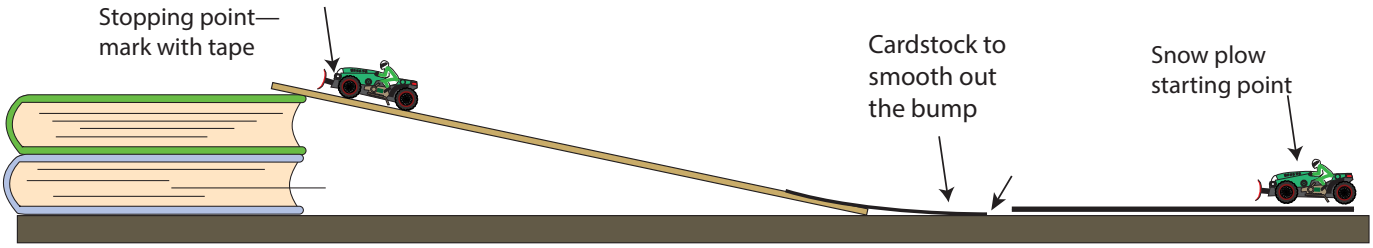
Road Surface Traction

Team Members: _____ _____

_____ _____

Instructions:

1. Select two of the simulated road surface materials available for comparison testing. Write the names of the materials in the data chart below. These materials will be compared to a smooth floor.
2. Begin with the smooth floor. Place the Hess Snow Plow 2 feet (~61 cm) from the lower end of the ramp. Wind up the plow's spring motor, place it on the road surface, and release it. Observe how far up the ramp the plow runs.
3. Adjust the angle of the ramp so that the plow runs up the ramp just short of its upper end. Keep it at that angle for all test runs.
4. Measure and record the distance from the lower end of the ramp to where the plow's front wheels stop. Mark the ramp with tape where the front wheels of the plow stop.



5. Place the first road surface you selected at the lower end of the ramp. Start the Hess Snow Plow from the marked starting point on the road surface and have it run across the road surface and up the ramp. Measure how far up the ramp the plow went and record it below. Repeat the test 2 more times. Record and average the 3 runs.
6. Replace the first road surface material with the second one. Repeat the 3 runs, and record and average the distances the plow rolled up the ramp.
7. Which of the two road surface materials provides better traction for the snow plow? Explain why.

Surface Material	Test 1	Test 2	Test 3	Average	How close did the plow come to the upper tape mark?

Additional Activity: Simulate wet road conditions by sprinkling water on an aluminum foil or wax paper surface. Observe how the wet surface affects the plow's traction.

03 Plow Blade Design

Student teams design, construct, and test a plow blade to help the hauler truck clear snow after an overnight snowstorm.

Suggested Grades 3–8

With modifications for younger children

Suggested Grades **3–8**
With modifications for younger children

03 Plow Blade Design

The Question

How does the shape of a snow plow blade affect how much snow it can remove from a roadway?

Where's the STEM

Every winter, snow plows work to keep roads safe by clearing away snow and ice to make driving safer. Snow plows are vehicles with plow blades attached to their front ends. City maintenance crews attach blades to garbage and dump trucks for winter use.

Engineers designed snow plow blades to push snow away from roads. Most plow blades are not perfectly straight. Instead, they are slightly curved and mounted at an angle. This design allows the blade to move snow off to one side of the road rather than pushing it directly in front of the vehicle.

The shape and angle of the blade have a major impact on how well the plow performs. A blade that is too flat may simply push snow straight ahead. A blade angled too much may make it harder to move the snow efficiently, requiring more passes of the plow to do its job.

Engineers also study the forces acting on the blade. As the truck moves forward, the blade exerts a force on the snow and the snow exerts an opposite force on the blade as it resists being moved. Engineers test new blade shapes, materials, and mounting angles to change how these forces are distributed. A better blade design will improve snow removal and make the job of clearing streets more efficient.

In this activity, teams of students will design, construct, and test their own snow plow blade design. Their community has just experienced a major snowstorm overnight and the community is snow bound. Can the Hess Hauler Truck be fitted with a snow plow blade to help clear the snow?

Materials

PER INVESTIGATION TEAM

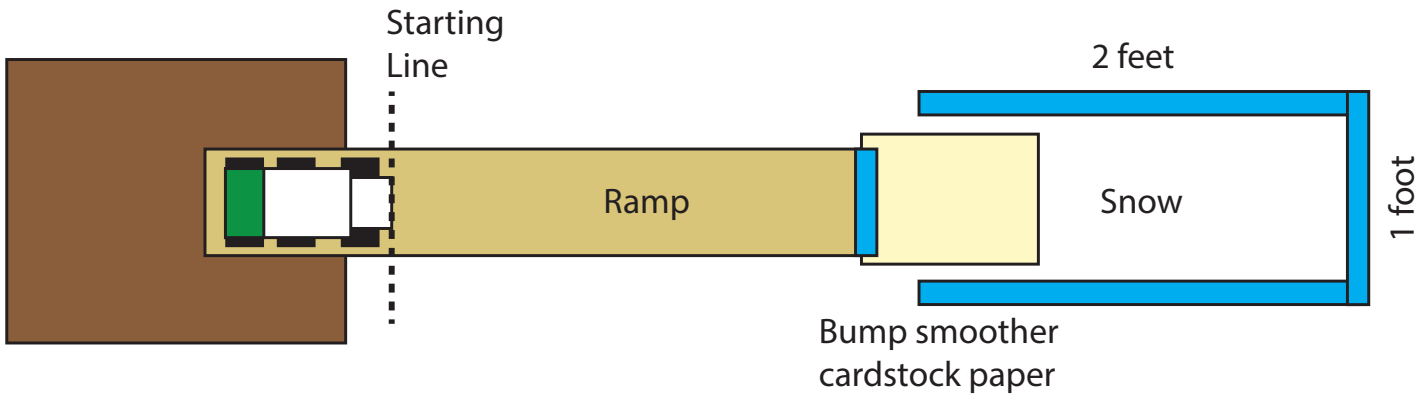
- Hess Hauler Truck
- index cards or cardstock paper
- masking tape
- scissors
- ruler
- "Plow Blade Design Challenge" student page

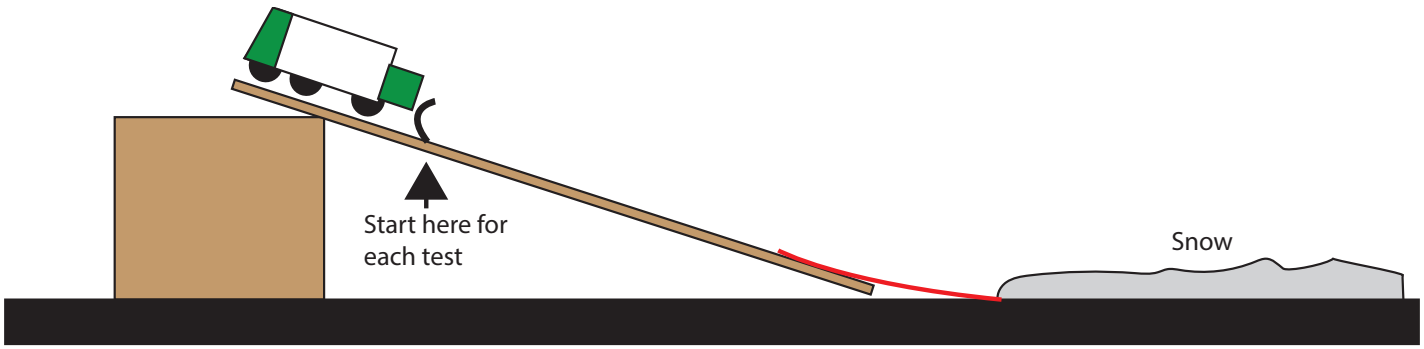
FOR THE CLASS

- a wood or cardboard smooth ramp approximately 3–4 feet (~ 1 meter) long
- smooth floor surface
- cotton balls or pompoms to represent snow
- painter's tape or masking tape to mark the roadway test area
- measuring tape
- cardboard box or book stack to elevate one end of the ramp

Management Tips

- Prepare the track for the plow blade tests. Elevate one end of the ramp with a cardboard box or stack of books. Tape a sheet of cardstock paper to the lower end of the ramp and floor to smooth out any bumps when the hauler truck reaches the floor.
- Mark a starting point for the front wheels of the Hess Hauler Truck at the top of the ramp.
- Place tape marker strips on the floor to represent a roadway test area, as shown below. Cover the test area with the same amount of simulated snow before each trial.
- Teams should release the hauler truck from the designated starting point at the upper end of the ramp. **Do not push the truck**.
- Make sure blade designs are securely attached to the front of the hauler truck but do not interfere with the wheels or steering.
- Encourage students to test, redesign, and improve their blades after each trial.
- Have students complete at least three trials for every blade design and average their results.





Procedure

01 Place construction materials in a convenient location in the classroom.

02 Describe the challenge of creating a plow blade for the Hess Hauler Truck using index cards or cardstock. Stress that students should be conservative in their use of the materials. In real life, keeping the cost of materials low is important.

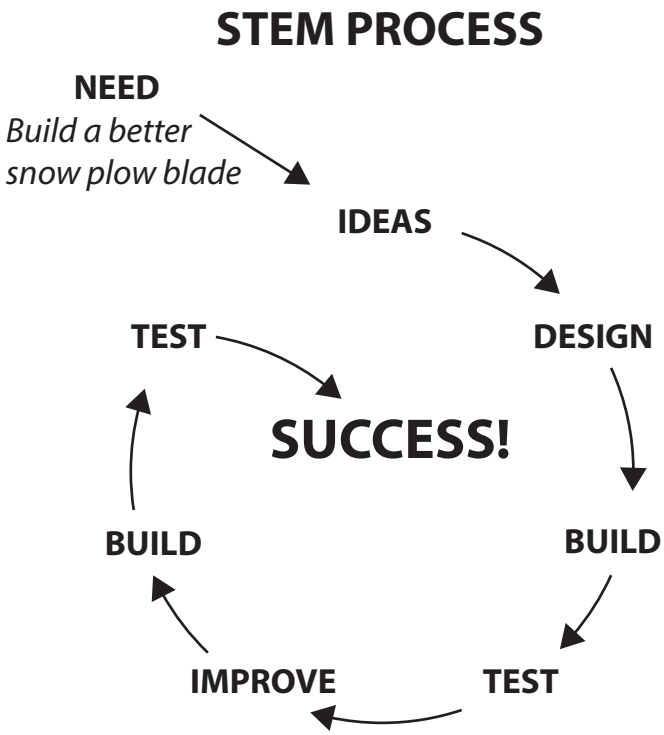
03 Encourage students to experiment with different blade shapes: straight, curved, angled, wide or narrow, and single-piece or multi-piece designs.

04 Demonstrate how to use the test area and how to release the Hess Hauler Truck down the ramp. Remind teams to start the hauler truck from the same marked point for each test.

05 Remind teams to reset the snow to look the same for each test.

Wrap It Up

- Ask each team to show and describe the features of their plow design.
- Which team's design seems to work the best?
- Which blade shape removed the most snow?
- How did the blade angle affect the direction the snow moved?
- How did the snow move: straight ahead, to the right or left, split in both right and left directions?
- Were there any advantages to having a wide blade? What disadvantage might a wide blade have? (Wide blades sweep a wider path through snow, which reduces the number of passes needed to clear a road. However, wide blades are more challenging to use when roads are narrow and lined with parked cars.)
- Remind students that having to modify initial designs for plow blades is a normal part of the STEM process. Engineers learn something from each test leading up to a successful design.



Additional Activities

- Challenge students to redesign their blade using fewer materials while maintaining or improving its snow-clearing performance. Students can compare the efficiency of each design by calculating how much snow was removed for every inch of cardboard used.
- For an additional engineering challenge, students can test their blade designs on different "snow" conditions by using cotton balls to represent light, powdery snow and crumpled paper to represent heavier, packed snow. Compare how each blade performs under different conditions and discuss why engineers design snow plows to work in a variety of winter weather scenarios.

Plow Blade Design Challenge

Team Members: _____ _____

_____ _____

Instructions:

1. Working as a team, discuss ideas for a new and improved snow plow blade design.
2. Sketch your best idea on the following page.
3. Construct your plow, attach it to the hauler truck, and try it on the ramp/snow field test area.
4. Conduct three test runs, and fill in the chart below for each run. For each test, start the hauler truck at the same marked spot at the upper end of the ramp. Cover the snow field with the same amount of snow for each run.
5. Average the measurements (length/width) for the area of snow cleared by the plow and the distance the plow pushed the snow.
6. Can your team come up with improvements on your initial design?

Trial	**Amount of snow moved** (Measure the length/width of the area cleared of snow)	**How far was the snow pushed from the lower end of the ramp?**	**How did the blade perform?**
Test 1			
Test 2			
Test 3			
Average			

Compare your blade design with those created by other teams, and discuss:

- Which blade shape removed the most snow?
- How did the blade angle affect the direction the snow moved?
- Did a wider blade perform better?
- What changes could improve your design?

Plow Blade Design Challenge

Sketch your plow blade design for the Hess Hauler Truck in the space below.

04 Plowing the Driveway

Student teams make a slight modification to the snow plow blade to simulate angling it to one side and determine whether this makes plowing easier.

Suggested Grades K–8

With modifications for younger children

Suggested Grades **K–8**
With modifications for younger children

04 Plowing the Driveway

The Question

How can you make plowing snow easier with the Hess Snow Plow?

Where's the STEM

In places where winter can be very snowy, snow piles up over the season and becomes progressively harder to remove from sidewalks and driveways. Snow takes many forms, from powdery and fluffy to heavy, wet snow with a high moisture content. Using a snow shovel to remove it is a back-breaking job. That's where the Hess Snow Plow comes in. The plow is an all-terrain vehicle (ATV) with a plow blade mounted in front.

The snow plow has heavy tread tires that get massive traction over any kind of road surface, especially road surfaces covered in snow. The plow blade has two positions: The up position is for driving around without moving material ahead of it, and the low position is for moving snow. In a full-size snow plow, the plow blade can also be tilted to the right or left to push snow to one side or the other. The Hess Snow Plow cannot tilt from one side to the other; an attachment is needed.

Both the blade tilt and the curvature on a plow work as a horizontal inclined plane to move the snow to the side. An inclined plane is one of the six kinds of simple machines in mechanics. The others are wheels and axles, levers, screws, wedges, and pulleys.

In this activity, a driveway leading up to a garage has to be plowed. Teams will use the plow to clear the drive. They will then make a slight modification to the plow blade to simulate the blade being tilted to one side to see if that makes plowing easier. The tilted plow blade design used here is based on what teams learned in the plow blade design activity. Teams will use the plow in a simulated real-life situation.

Materials

PER INVESTIGATION TEAM

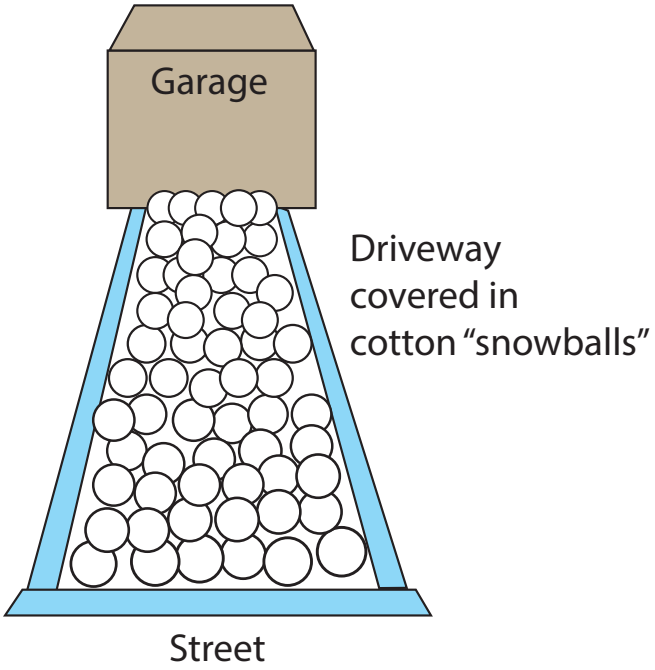
- Hess Hauler Truck and Snow Plow
- "Blade Attachment" pattern
- "Plowing the Driveway" student page
- scissors

FOR THE CLASS

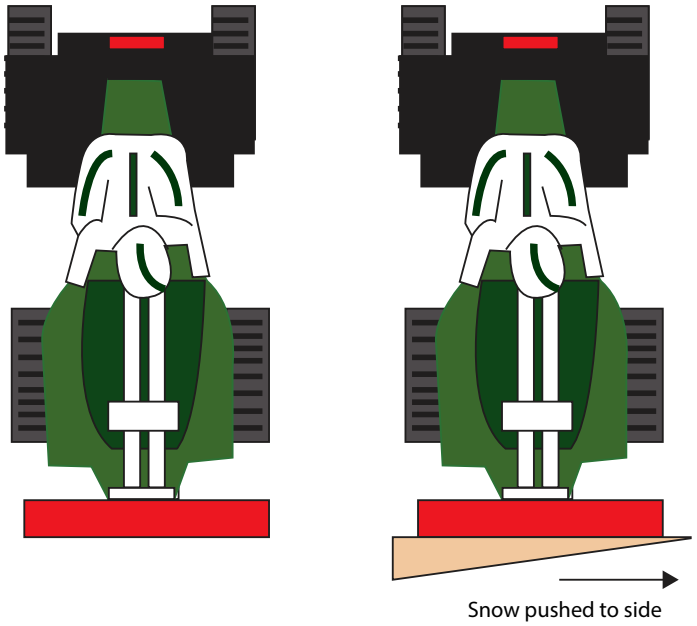
- ultra-low-temp glue gun and glue
- glue stick
- painter's or masking tape
- small cardboard boxes, such as shoe boxes, to represent the garage (if not available, piles of books can be used)
- cotton balls or pompoms to simulate snow

Management Tips

- Prepare several test areas for teams to hone their plowing skills. A test area will consist of two parallel strips of tape about 40 inches (~ 1 meter) long and 10 inches (~ 25 centimeters) wide.
- The area between the tape strips represents a driveway from a street to a garage. Place a small box at one end of each driveway for the garage. Fill the space between the tape strips with the simulated snow.
- Teams may be tempted to plow the snow from the garage to the end of the driveway. Remind them that the ends of the driveways open onto streets and cannot be blocked. Snow will have to be removed from the driveway but not piled up at one end or the other.
- In the second part of the activity, teams will make a plow attachment out of cardstock paper. Print the pattern and the construction instructions below on the cardstock.
- The attachment consists of a wedge shape simulating the plow tilting to one side. Use the glue stick to join the pieces of the pattern to form the wedge. The wedge shape takes just a few moments to glue well, and one glue stick is sufficient for the class.
- Attach the wedge to the plow blade as shown below by putting small drops of hot glue on the blade's four corners. Do this task for your students. Align the wedge to the glue dots, press lightly, and let cool.
- At the conclusion of the activity, remove the wedges from the Hess Snow Plow and pick off the hardened hot glue with a fingernail. The glue will not damage the plow blade.



Hess Snow Plow with and without attachment



Procedure

01 Explain the task to the teams: A heavy snowstorm has covered your driveway and you can't drive your car out of the garage. The driveway needs to be plowed. Show teams the garage/driveway model they will plow.

02 Provide the "Plowing the Driveway" student page. When teams have plowed the driveway and counted the passes needed to do the job, help them assemble the paper plow attachment to simulate the plow blade tilting.

03 Reset the simulated snow using the same amount as in the first trial and have them plow again.

Wrap It Up

- Ask teams to describe their success in plowing the snow off the driveway. Where did they put the plowed snow? How many passes of the plow did it take? Why did the tilted plow require fewer passes?
- Ask teams to describe their strategies for plowing. Which direction, right or left, did the plow tilt? Which side of the driveway did they start the plowing?
- Why is it important to have fewer passes of the plow to do the job? Imagine having a plowing business. The more passes you make, the more gasoline you use, the more time the job takes, and the more it costs to do the job. Fewer passes means less gas, less time to do the job. Packing more jobs into the day means higher profits!

Additional Activities

- During especially heavy snow seasons, cities find themselves in a dilemma. Snowbanks become so large that no more snow can be piled on them by the plows. The snow has to be taken from the streets to parks and vacant lots and dropped off there until spring. That becomes a job for the Hess Hauler Truck.
- Challenge teams to fill the truck with simulated snow and transport it to a designated spot on the classroom floor.
  - Use the spring motor of the plow to push snow into the hauler truck and then close it.
  - Push the hauler across the floor to the dump site, empty it, and return to the snow pile as many times as necessary to clear the snow pile.
  - Discuss any ideas students might have to improve this slow and tedious process.

Blade Attachment Pattern - Assembly Instructions

01 Use a straightedge ruler and a ballpoint pen to score all the dashed lines. (Indentations with the pen will make folding the blade attachment easier.)

02 Cut along the solid lines only.

03 Fold tabs A and C under.

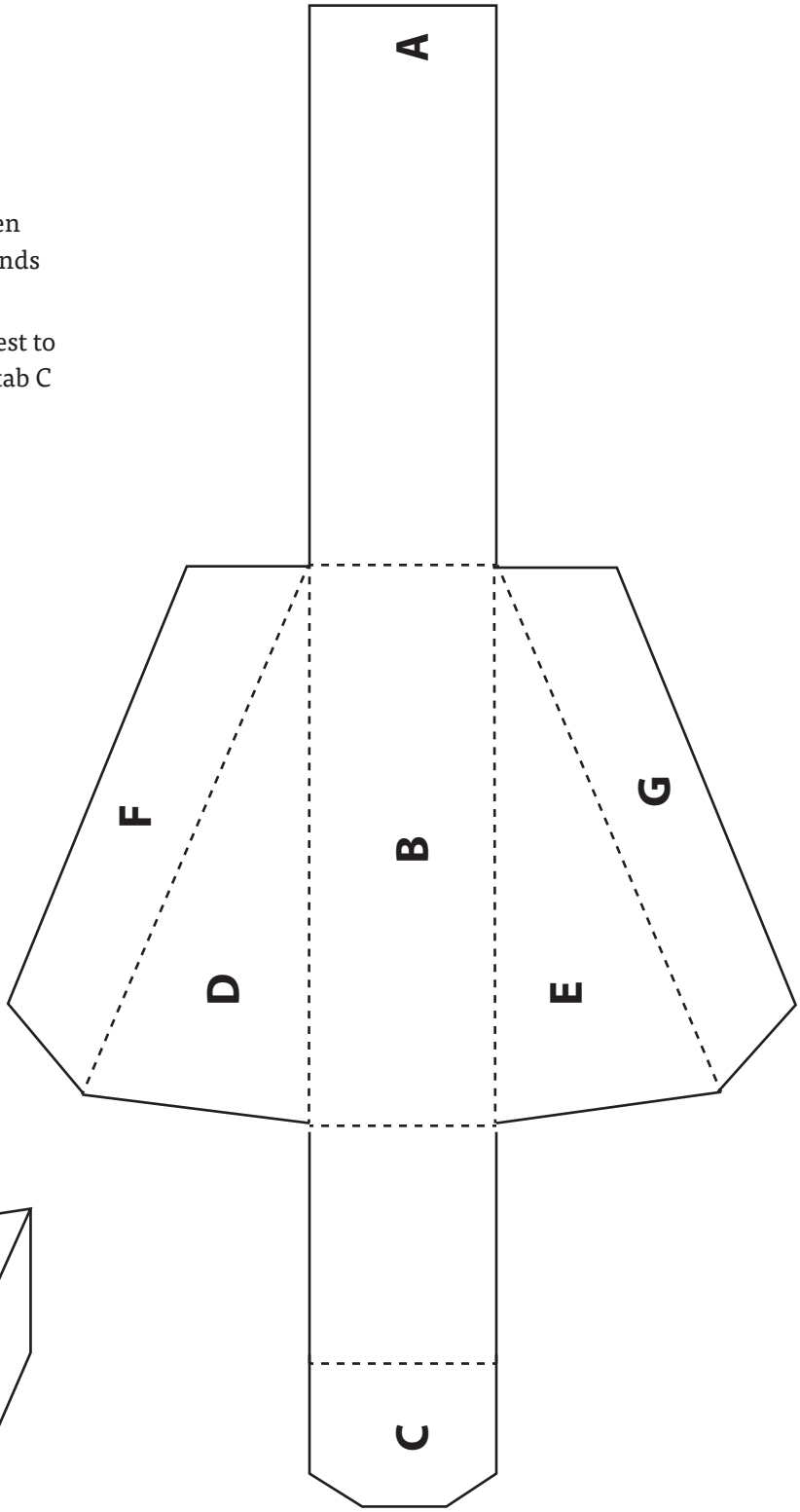
04 Fold tabs D and E under.

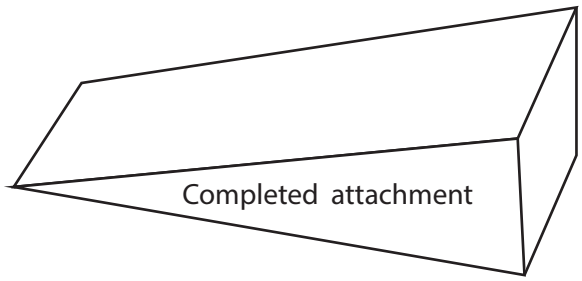
05 Fold tabs F and G under.

06 Apply a coat of glue to the underside of tab A, then press tab A over tabs F and G. Hold for a few seconds until they stick together.

07 Fold tab C on the dotted line (the dotted line closest to the letter C). Apply glue to coat the underside of tab C and press it onto tab A until it sticks.

08 Let all the glue dry before attaching it to the Hess Snow Plow.





Plowing the Driveway

Team Members: _____ _____

_____ _____

Instructions:

1. Use your Hess Snow Plow to clear the snow on the driveway from the street to the garage. Snow **may not** be piled up on the street or in front of the garage.
2. Count and record below how many passes of the plow are needed to clear the driveway.
3. Design and construct an attachment for your plow that pushes snow to one side as the plow moves forward. Use the back of this page to sketch your plow attachment design.
4. Reset the snow and plow again. Count and record below how many passes of the plow are needed to clear the driveway with the attachment in place.

Snow plow without any attachments	**Snow plow with attachments**
Number of passes to plow the driveway: ☐	Number of passes to plow the driveway: ☐

Answer these questions:

1. Did the plow with the attachment do a better job of plowing? Describe and explain what happened below.

2. How would you improve your attachment design to make it more efficient at plowing? Describe below.

05 Newton's Laws

Student teams use the snow plow to investigate each of Isaac Newton's three laws of motion.

Suggested Grades 6–8

With modifications for younger children

Suggested Grades **6–8**
With modifications for younger children

05 Newton's Laws

The Question

How do Newton's laws of motion apply to the Hess Snow Plow?

Where's the STEM

You have probably heard the story about the observation made by the great English scientist Sir Isaac Newton (1643–1727) when he saw an apple fall from a tree. He wondered why the apple fell straight to the ground rather than in some other direction. This observation led to his study of gravity and inspired his famous law of gravity. The law of gravity was just one of his important scientific studies. Among many other accomplishments, he stated three laws of motion.

Newton's first law of motion, also known as the law of inertia, describes the resistance of all objects to a change in motion.

> **An object at rest remains at rest, and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force.**

The Hess Snow Plow will remain in the same place unless an unbalanced force is applied. The plow changes from rest to motion when the spring motor is wound and the plow is released. The turning wheels allow the plow to shoot forward in a straight line. When the spring fully unwinds, there is no longer a force propelling the plow, so it coasts until friction with the floor acts as an unbalanced force and brings it to a stop.

The direction in which the plow is moving can change only if an unbalanced force is applied, such as a push from one side or the other. When the unbalanced force stops, the plow will resume a straight-line path in the direction it was traveling when the force stopped.

Newton's second law of motion is an equation that describes the relationship of force, mass, and acceleration, or the rate at which the velocity changes.

> **Force equals mass times acceleration, or F = MA.**

The equation can be written in two other ways: M = F/A or A = F/M. As long as you know two of the factors, you can calculate the third. For example, if you know the amount of force applied to an object and how much the object accelerates, you can calculate the object's mass.

Newton's third law of motion describes how forces occur in pairs.

> **For every action (force), there is an equal and opposite reaction (force).**

This law is best seen by watching a rocket lift off. The gases produced by burning propellant shoot downward from the engines. They exert an equal and opposite force on the rocket, causing it to climb toward space.

All motion involves action/reaction forces. These forces can start an object moving, stop an object moving, or change an object's speed or direction. In this activity, teams will use the Hess Snow Plow to investigate each of Isaac Newton's three laws of motion.

Materials

PER INVESTIGATION TEAM

- Hess Snow Plow
- "Isaac Newton's Laws of Motion" student page
- 5 x 8-inch (~13 cm x ~20 cm) rectangle of thin cardboard
- 8 straight drinking straws
- 60 inches (~152 cm) of cotton string or yarn
- 2 inches (~5 cm) of painters tape or masking tape
- ruler

FOR THE CLASS

- one or more cleared tabletops

Management Tips

- For the first part of the activity, show teams how to tie the string to the plow blade supports. If they tie it anywhere else, the plow may not curve.
- For the last investigation, demonstrate how to set up the straws, cardboard, and plow.
  After teams have tried the first run, show them how to measure the movement of the plow.
  - The measurement starts with the location of the rear power wheels before the plow is released.
  - Use a piece of painter's or masking tape to mark the wheel position.
  - When the plow is released, it will travel a very short distance through the air before the rear wheels land on the tabletop.
  - Mark the first spot where the rear wheels touch the tabletop. Measure the distance between the tape marks.

Procedure

Newton's first law of motion

01 Have teams tie a string loop around the blade of the Hess Snow Plow.

02 One team member will wind up the spring motor to add potential energy to it.

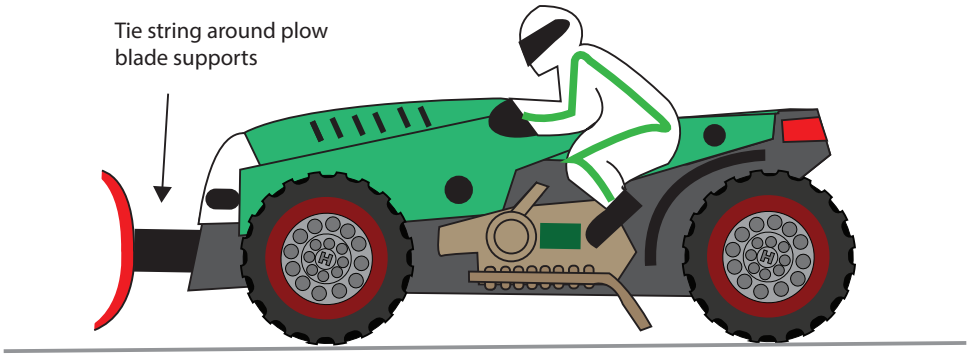
03 A second team member will hold the other end of the string taut.

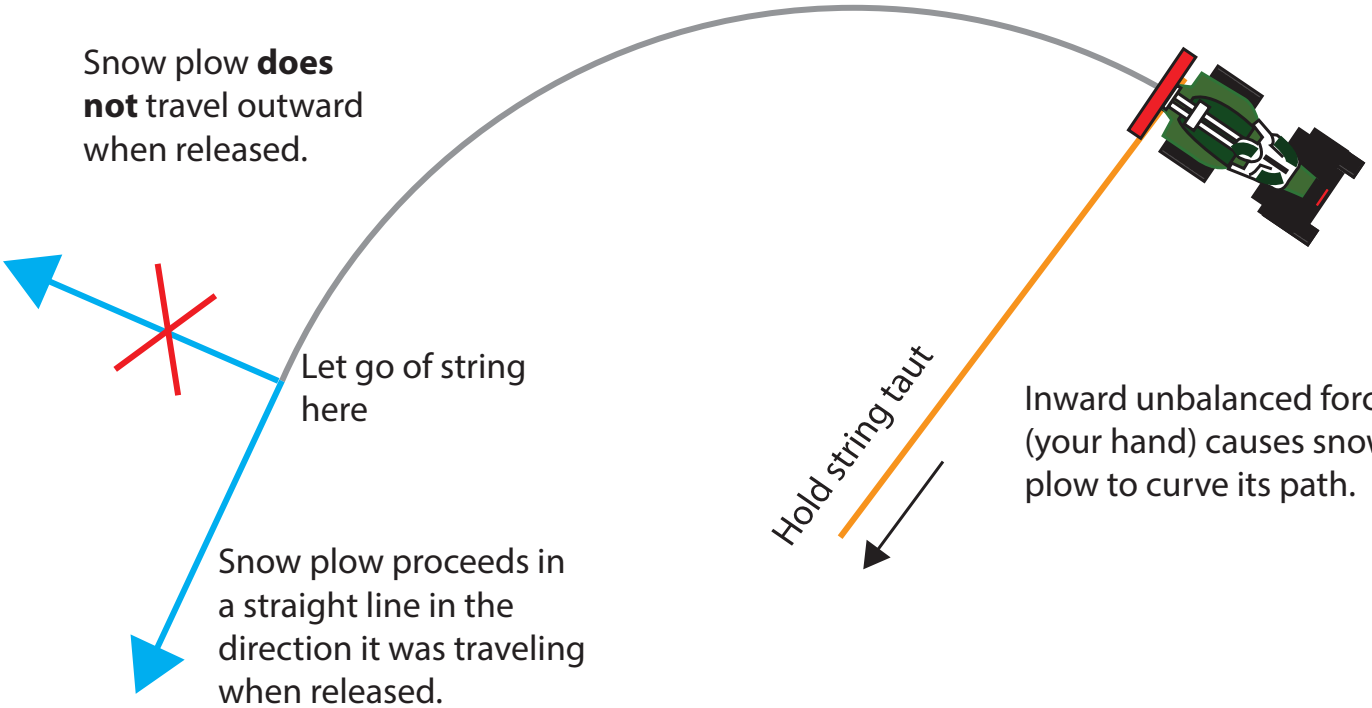
04 When the first team member releases the plow, the potential energy stored in the spring is converted to kinetic energy. However, instead of traveling in a straight line, the string exerts an inward unbalanced force, causing the plow to curve.

05 The student holding the string releases it after the plow has traveled partway along its curved path. Team members should observe how the plow returns to a straight-line path in the direction it was traveling when the string was released.

06 Have teams repeat the procedure several times and switch jobs so that all team members can hold the string.

07 Team members should describe their observations and answer the questions about the first law of motion on the student page.





Procedure Continued

Newton's second and third laws of motion

01 Have teams place eight straight straws on a smooth tabletop as shown in the first picture below (the red circles indicate openings from a head-on view). Place the cardboard rectangle on top as shown. Use a small piece of tape to mark the position on the cardboard where the plow's rear wheel should sit.

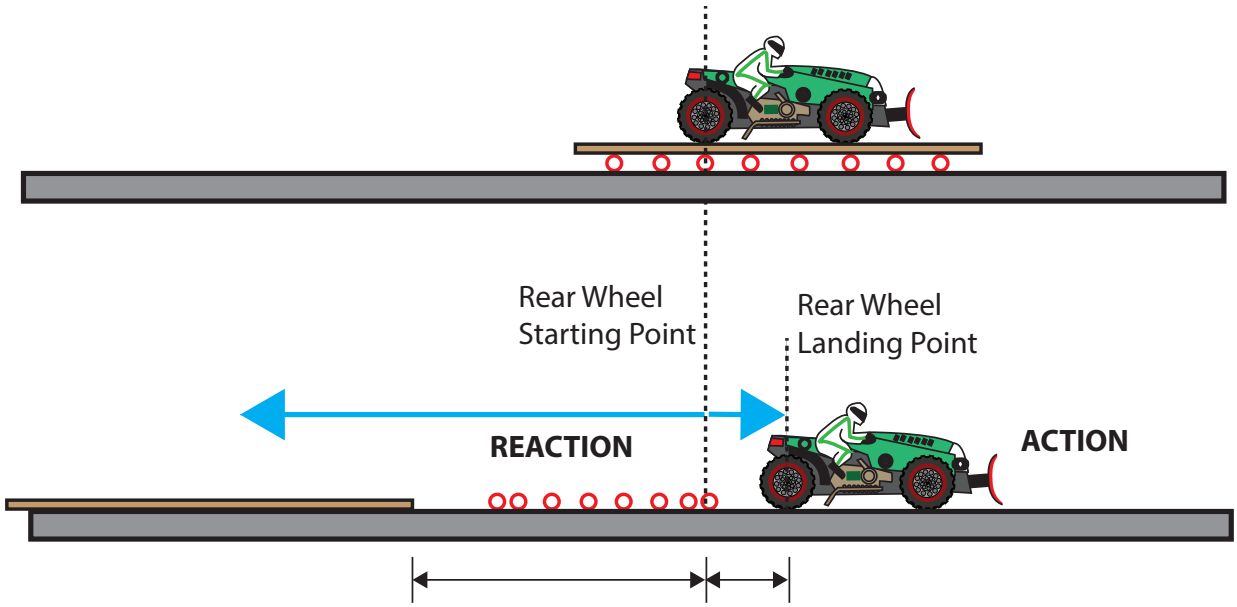
02 When ready for the test, fully wind the plow's spring motor and place the plow on the cardboard as shown.

03 Release the plow so that it runs off the cardboard. Observe where the plow drops to the tabletop—use a piece of tape to mark the exact point where the rear wheels first touch the tabletop. Measure the distance between the two tape marks.

04 Teams should also measure how far the cardboard moved from its starting position when the plow moved off the cardboard in the opposite direction.

05 Teams should repeat the test two more times and record the measurements on the student page.

06 Team members should also describe their observations and answer questions for the second and third laws of motion on the student page.



Measure how far the cardboard moved and how far the plow moved at rear-wheel landing point.

Wrap It Up

- In the first activity, the Hess Snow Plow curved in an arc because the string exerted an inward unbalanced force on the plow. When the string was released, the plow moved in a straight line in the direction it was traveling at the moment the string was released. Refer back to the description of Newton's first law of motion on the first page of this activity.
- How does this demonstration of the first law of motion relate to riding in a car as a passenger when the driver makes a fast turn to the left? The passenger is pressed against the right-side door and may perceive this as an outward pulling force. In reality, the passenger's body tends to keep moving in a straight line because of inertia. As the car turns left, the right-side door exerts a force on the passenger that changes the passenger's direction of motion. Another good example is how people's bodies are thrown from side to side or up and down on a roller coaster. Ask students if they can think of other examples.
- The second activity demonstrates both Newton's second and third laws of motion. Review the description of these laws on the first page of this activity.
- The demonstration of the third law can be observed when the plow's motor releases stored potential energy, causing the plow and the cardboard to exert equal and opposite forces on each other. Both travel in opposite directions—action and reaction.
- Things get tricky when demonstrating the second law. Careful observation by the students is needed. The distance the plow moves when it jumps off the cardboard is very short. Measuring from where the wheels are stationary to where they first touch the tabletop is important.
- The plow motor still has potential energy to release, and the motor keeps running. Its continued motion is not part of the demonstration. With careful observation, students will see that the cardboard travels much farther than the plow. Why? The answer is mass. The plow has a much greater mass than the cardboard.
- The equation for the second law is F = MA. The third law's action-and-reaction principle is the same for both the plow and the cardboard. The equation can be written as follows:

  MA = F = MA
  (plow) (cardboard)

  Since both sides are equal to F, the F can be dropped.

  MA = MA

- The plow has a larger mass than the cardboard, so its acceleration is smaller. The cardboard has a smaller mass, so its acceleration is larger. Consequently, the cardboard travels farther than the plow. This keeps the equation balanced.

Additional Activity

- Challenge students to come up with other examples of Newton's laws of motion.
- Have teams try the first law of motion activity using the hauler. Because it doesn't have a spring motor, one student will need to push it while another holds the end of the string in place. The location of the string attachment to the hauler may require some adjusting for this to work. Show what happens to the plow if the string is attached in different locations other than around the plow blade. The unbalanced force of the string may result in erratic movement of the plow.

Isaac Newton's Laws of Motion

Team Members: _____ _____

_____ _____

Investigations *(Use the back of this page if you need more space for your answers.)*

Investigation 1

- Test-drive the snow plow: Wind it up, place it on the floor, and let it go.
- If the plow runs straight, you are ready for the next part. If not, check the tires to see if they are dirty and clean them. Try the run again.
    - Where did the plow get the energy to travel? Use the terms **potential energy** and **kinetic energy** in your answer.

Investigation 2

- Tie the string to the snow plow blade supports as shown by your teacher.
- Choose one team member to hold the other end of the string and a second team member to wind the spring motor of the plow.
- Place the plow on the floor and press the end of the string against the floor as well. Do not move the end of the string. Let go of the plow.
    - Describe what happened and why.

Investigation 3

- Follow the directions provided by your teacher for this next part.
- You will need 8 drinking straws, a cardboard rectangle, and the snow plow.
- Lay the straws on the tabletop like railroad ties.
- Place the cardboard on top of the straws and the fully wound plow on top of the cardboard.
- Release the plow and observe what happens. Repeat as often as needed.
    - Describe what happened and why.
    - How far did the snow plow travel from its starting point to where the rear wheels landed on the tabletop?
    - How far did the cardboard platform travel from its starting point? Explain why there is a difference.

06 Bridge to the Recycling Center

Student teams design and build a bridge that allows the hauler truck to safely carry as much waste material as possible across the river.

Suggested Grades 3–8

With modifications for younger children

Suggested Grades **3–8**
With modifications for younger children

06 Bridge to the Recycling Center

The Question

How does the design of a bridge affect the amount of weight it can safely support?

Where's the STEM

Bridges are one of the most important parts of our transportation system. Every day, they allow cars, buses, and trucks to safely cross rivers, valleys, and intersecting highways. When engineers design bridges, they use construction materials efficiently while ensuring that the bridges remain strong and safe and can support vehicles of all sizes.

Whenever a vehicle crosses a bridge, the vehicle applies a load (the weight of the vehicle and its cargo) that exerts a downward force on the bridge. The bridge must support this load plus its own weight. These combined weights exert a downward force on the bridge. At the same time, the ground and the bridge exert a force upward to support the weight of the vehicles traveling across it. If a bridge is not strong enough to support the combined weight, it may sag, crack, or collapse.

Other forces are also at work on bridges. Compression is a squeezing force that pushes materials together, like squeezing a sponge from both ends. Tension is a pulling force that stretches materials apart, like pulling a rope from both ends. A successful bridge is designed so that its different parts work together to safely handle both types of forces.

Civil and structural engineers choose a bridge design based on many factors, including the distance the bridge must span, the amount of weight it will carry, the surrounding environment, construction costs, and the materials available. There is no single "best" bridge. Every design involves tradeoffs between strength, efficiency, cost, and ease of construction.

Civil and structural engineers rarely build a bridge perfectly on the first attempt. Instead, they follow the engineering design process by asking questions, imagining solutions, planning, creating, testing, improving, and communicating their results. Testing allows engineers to identify weak points, redesign their structures, and make improvements before the bridge is ever used by the public.

For this activity imagine an early thaw from a heavy winter storm has washed away the only bridge connecting your community to the recycling center. Without a safe bridge, trucks cannot transport waste, and the community quickly begins to fill with recyclable materials and trash. Your challenge is to think like a civil engineer by designing and building a bridge that allows the Hess Hauler Truck to carry as much waste material as possible safely across the river.

Materials

PER INVESTIGATION TEAM

- Hess Hauler Truck
- craft sticks
- white or hot glue
- masking tape
- string (optional)
- cardboard (optional)
- pennies, washers, marbles, or other small weights
- "Bridge to the Recycling Center" student page

FOR THE CLASS

- 2 desks or stacks of books to create a 12-inch (~30cm) bridge gap
- ruler or measuring tape
- weights for testing
- "Common Bridge Designs" graphic (next page)

Management Tips

- Set up two tables end to end with a 12-inch (~30cm) gap. As an alternate, use two stacks of books to create the gap.
- When constructing the bridge, allow adequate drying time if glue is used.
- Test each bridge using the Hess Hauler Truck containing the same amount of weight for consistency.
- Add weights one at a time to prevent sudden failures.
- Encourage students to redesign rather than simply rebuild after testing.

Procedure

01 Tell teams that the bridge to the town's recycling center has been washed out by flooding from melting snow. Challenge teams to design and build a bridge that allows the hauler truck to safely carry as much weight as possible across the river.

02 Project and discuss the "Common Bridge Designs" graphic. Explain that teams can use one of these designs or come up with a new design for the bridge and then build it.

03 Show teams the 12-inch (~30 cm) gap their bridge will have to span.

04 Point out the materials and tools available for construction.

05 Tell teams they will place the hauler truck on the bridge they constructed to see if it will support the load. If it does, weights will be gradually added to the truck to increase the load until the bridge fails. This is called destructive testing.

Common Bridge Designs

Engineers have developed many different bridge designs, each with its own advantages.

A **beam bridge** is the simplest type of bridge. It uses one or more horizontal beams supported at each end. Beam bridges are relatively easy to build and work well for short distances, but they are not ideal for spanning very long gaps because the beams can bend under heavy loads.

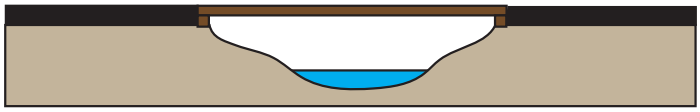
An **arch bridge** uses a curved arch beneath the roadway. The curved shape directs much of the load outward and downward into the supports at each end, making arch bridges incredibly strong. Many stone bridges built hundreds of years ago are still standing today because of this efficient design.

A **truss bridge** uses a framework of connected triangles. The truss is one of the strongest structural designs because triangles help distribute forces throughout the bridge and resist bending. Truss bridges are commonly used for railroad and highway bridges because they provide excellent strength while using relatively little material.

A **suspension bridge** supports the roadway using large cables suspended between tall towers. The towers carry the weight downward, while the cables experience tension. Suspension bridges can span very long distances, making them ideal for crossing wide rivers and bays. Famous examples include the Golden Gate Bridge and the Brooklyn Bridge.

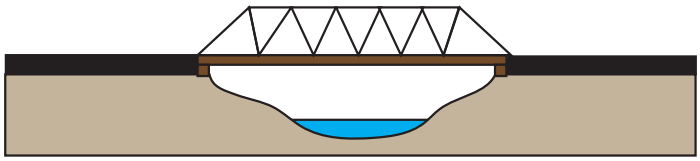
A **cable-stayed bridge** also uses cables connected to tall towers, but unlike a suspension bridge, the cables attach directly from the towers to the roadway. This design provides excellent strength while requiring fewer cables and has become a popular choice for many modern bridges.

BEAM BRIDGE

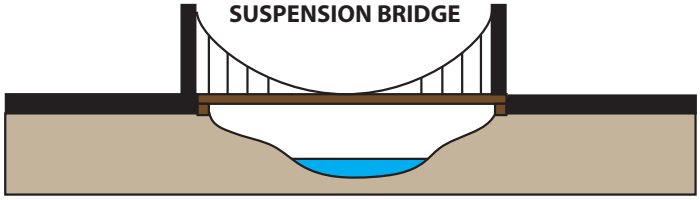


ARCH BRIDGE

TRUSS BRIDGE

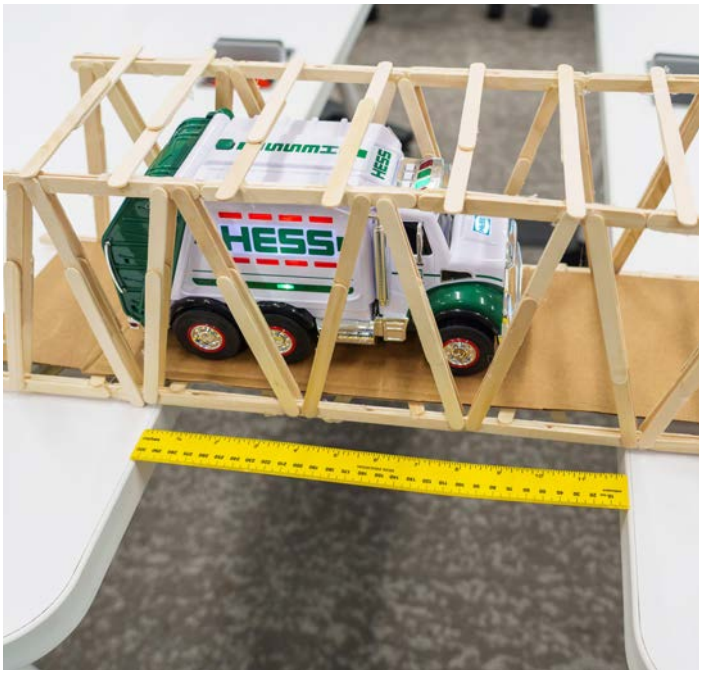


SUSPENSION BRIDGE



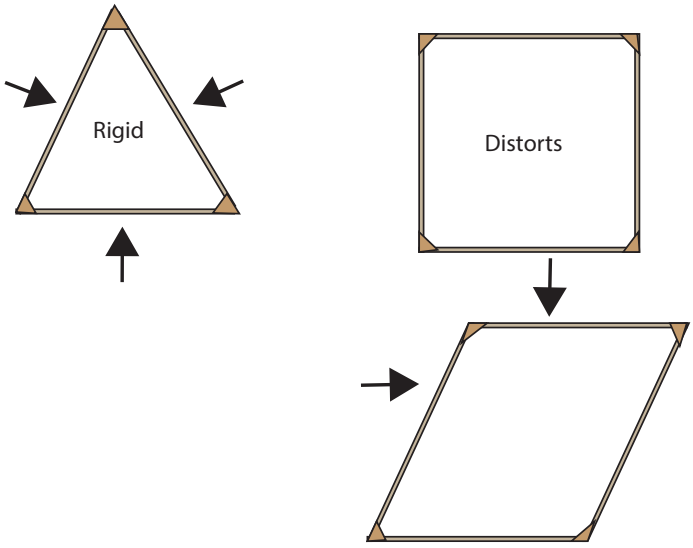
Wrap It Up

- Ask teams to report on their bridge designs. Which bridge designs supported the most weight? Where did the bridge structure begin to fail?
- Why is testing an important part of engineering? Explain that engineers must balance strength, safety, and the amount of material they use. A successful bridge is not always the one that uses the most materials but the one that uses the materials most efficiently. Through testing and redesign, engineers create bridges that safely support vehicles and communities for many years.
- Review common bridge designs in actual use.



Additional Activity

- Have students investigate why the truss bridge design works for a heavy vehicle.
- Compare the strength of a triangle and a square: Use three wooden chopsticks or skewers and masking tape to make a triangle, and four wooden chopsticks or skewers to make a square. Which shape is stronger?



Bridge to the Recycling Center

Team Members: _____ _____

_____ _____

Instructions:

1. Meet with your team and discuss ideas for the replacement bridge. The bridge must be long enough to span a 12-inch (~30 cm) gap with room to spare and sturdy enough to support the Hess Hauler Truck and Snow Plow.
2. Draw your design on the back of this page.
3. Construct the bridge
4. Place the bridge over the gap between the tables or book piles.
5. Place the hauler truck in the middle of the bridge span.
6. If the bridge does not support the truck, reinforce it or change the design.
7. Test again. If the bridge holds, predict the maximum weight it can support (truck weight plus added weights). Test your prediction and record your data below.

Data Table

Trial	Number of Weights Held (truck plus weights)	Did the bridge fail?
Prediction		
Test 1		
Test 2		

If the bridge failed, what part of the structure sagged or broke? Why?

How could you improve your design to make it stronger?

07 Hauling Mass

Student teams investigate how the mass of the hauler truck and its load affects the truck's forward motion.

Suggested Grades 3–8

With modifications for younger children

07 Hauling Mass

The Question

How does the mass of the Hess Hauler Truck affect how it moves?

Where's the STEM

During the off-season, the Hess Hauler Truck can serve as a garbage truck. Every day, garbage trucks transport thousands of pounds of trash and recycling materials. Some loads are light. Others can be extremely heavy. Transportation engineers have designed trucks that can safely carry heavy loads while remaining stable, efficient, and easy to control. Understanding how the total mass (truck and load) affects vehicle performance helps engineers design better trucks for the future, safer roads, and more efficient transportation systems.

One of the most important factors affecting a moving vehicle is its total mass. When serving as a garbage truck, the hauler's mass increases as it fills with waste. Greater mass requires more energy to move and more force to speed up or slow down.

When climbing a hill, the hauler's gravitational potential energy increases as it moves against gravity. Going downhill, gravity changes potential energy into kinetic energy. Braking becomes necessary to keep the truck under control. In this situation, as in all other motion, the truck's total mass is an important factor.

In this activity, teams will investigate how different masses of the truck and its load affect forward motion.

Materials

PER INVESTIGATION TEAM

- Hess Hauler Truck and Snow Plow
- small weights (washers, pennies, or metal nuts)
- small container to store the weights
- kitchen scale or beam balance to measure mass
- ruler or measuring tape
- "Hauling Mass" student page

FOR THE CLASS

- painter's tape
- smooth floor surface

Management Tips

- Use painter's tape to mark a starting line on the floor for the hauler's front wheels.
- Use a kitchen scale or beam balance to determine the mass of the weights. Teams will need a total of about 60 grams of weights to add to the hauler.
- When adding weights to the hauler, encourage students to distribute the weights evenly across the hauler's compartment floor. This will ensure that the weight is balanced and no side of the hauler is heavier.
- Complete at least three trials for every mass test and average the results.

Procedure

01 Discuss the relationship between kinetic and potential energy with your students. Potential energy is stored energy, such as the energy in a wound spring or the energy stored when an object is elevated. When the wound spring of the Hess Snow Plow is released, or when an object falls due to gravity, potential energy is converted to kinetic energy. Kinetic energy is energy in motion.

02 Define mass and weight. Mass is the amount of matter in an object and is usually measured in grams or kilograms. Weight is the force of gravity acting on an object and is commonly measured in ounces or pounds. Weight depends on the strength of gravity where the object is located. However, mass does not change, no matter where the object is located.

03 For example, an exercise hand weight with a mass that corresponds to a weight of 10 pounds on Earth would weigh only about 1.7 pounds on the moon. The difference is due to the difference in the strength of gravity on Earth and the moon. However, the mass (amount of matter) of the hand weight remains the same on Earth and on the moon.

04 Explain that they will explore how added mass affects the distance traveled by the Hess hauler. Provide teams with the "Hauling Mass" student page and review the instructions.

05 Next, place the front wheels of the hauler on the starting tape. Wind up the plow's spring motor and place it in contact with the rear of the hauler. Explain that they will let the plow push the hauler, then measure how far the hauler travels.

06 Point out that teams will begin by conducting three test runs with an empty hauler.

07 **Box A**: Measure, in grams, a portion of the objects provided (washers, pennies, or nuts) and record that on the data table. Add the mass to the hauler. Remind teams to distribute objects evenly across the cargo area. Test the hauler with the added mass three times.

08 **Box B**: Measure, in grams, another portion of the objects provided. Add this to the mass from box A and record as "Added Mass = A+B." Remind teams to distribute objects evenly across the cargo area. Test the hauler with the added mass three times.

09 **Box C**: Measure, in grams, another portion of the objects provided. Add this to the mass from A and B and record as "Added Mass = A+B+C." Remind teams to distribute objects evenly across the cargo area. Test the hauler with the added mass three times.

10 After all runs have been completed, they will average the distances traveled for each loading condition.

Wrap It Up

- Review the procedure for the investigation. Have teams report on the distance traveled by the empty hauler and the loaded hauler. How did increasing the hauler's mass affect the distance traveled?
- Isaac Newton's first law of motion helps explain the results. It takes an unbalanced force to change the motion of an object. The hauler resists the change from rest to moving. This resistance is called inertia. Because the loaded hauler has greater mass, it has greater inertia and requires more force to change its motion.
- Transportation engineers study how energy, force, and mass work together when designing vehicles. Garbage trucks must safely carry heavy loads while remaining efficient and easy to control. By testing different loads under controlled conditions, engineers can improve vehicle performance and make transportation systems safer.
- One of the controlled conditions engineers consider is the steepness of hills. The higher the hill, the more potential energy the truck has. As the truck rolls downhill, gravity converts potential energy into kinetic energy, the energy of motion. A heavy truck needs powerful brakes to safely control its speed going downhill.
- Another factor engineers consider is the force needed to move a vehicle. A force is a push or pull that can change an object's motion. Engineers study how much force is needed to move vehicles carrying different amounts of mass. More massive vehicles require greater forces to accelerate and stop than lighter vehicles.
- Transportation engineers seek to design trucks that are fuel efficient, can carry large loads, and can transport heavy loads without sacrificing safety.

Additional Activity

- Have students conduct hauler tests with a ramp. Using the ramp design in the "Plow Blade Design" activity (page 15), investigate how different ramp heights and truck mass affect the distance the hauler rolls.

Hauling Mass

Team Members: _____ _____

_____ _____

Instructions:

1. Place the front wheels of the empty hauler truck on the starting line.
2. Wind up the plow's spring motor and place it in contact with the rear of the hauler.
3. Let the plow push the hauler, then measure how far the hauler travels. Repeat for a total of 3 test runs.
4. Box A: Measure, in grams, a portion of objects (washers, pennies, or nuts) and record on the data table as "Added Mass." Remember to distribute objects evenly across the cargo area. Conduct 3 test runs.
5. Box B: Measure, in grams, another portion of objects (washers, pennies, or nuts) and record on the data table as "Added Mass = A+B." Remember to distribute objects evenly across the cargo area. Conduct 3 test runs.
6. Box C: Measure, in grams, another portion of objects (washers, pennies, or nuts) and record on the data table as "Added Mass = A+B+C." Remember to distribute objects evenly across the cargo area. Conduct 3 test runs.
7. After all runs have been completed, average the totals.

			A	B	C
	Test Run	Empty Hauler	Added Mass =	Added Mass = A+B	Added Mass = A+B+C
Distance	1				
	2				
	3				
	Average				

Questions (answer on the back of this page):

- Which traveled farther: the empty hauler or the hauler with the added mass? Why?

Glossary

Terms

Acceleration: A change in how fast something is moving, and/or a change in its direction.
Action and reaction: A pair of equal and opposite forces that occur when two objects interact.
Angle: The amount that a line or surface is tilted compared with another line or surface.
Arch bridge: A bridge that uses a curved arch to support a load and transfer forces toward its supports.
Average speed: The total distance traveled divided by the amount of time it takes to travel that distance.
Axle: A rod that connects to a wheel and allows the wheel to rotate.
Beam bridge: A bridge that uses horizontal beams supported at each end.
Blade: The large attachment mounted to the front of a snow plow that pushes and moves snow or other material.
Cable-stayed bridge: A bridge that uses cables connected directly from towers to the roadway to support the bridge.
Centripetal force: A force that pulls something toward the center of a circle and keeps it moving around a curve.
Circumference: The distance around the outside of a circle.
Compression: A squeezing force that pushes materials together.
Deceleration: Slowing down.
Destructive testing: Intentionally breaking, crushing, or ruining an object to see how much stress, weight, or force it can take before it actually falls apart.
Drive wheel: A wheel that receives force from a vehicle's motor and helps move the vehicle.
Drag: A force that slows things down when they move through air.
Efficiency: How well a design performs while using as little material, energy, time, or effort as possible.
Force: A push or pull that can change an object's motion or shape.
Friction: The force that resists motion when two surfaces rub against each other.
Gravity: The force that attracts objects toward Earth.
Gravitational potential energy: Stored energy an object has because of its height above the ground.
Inclined plane: A sloped surface that makes it easier to move an object between different heights.
Inertia: The tendency of an object to resist a change in its motion.
Kinetic energy: The energy an object has because it is moving.
Load: The weight or force that a structure or vehicle must support or carry.
Mass: The amount of matter in an object.
Mechanical engineer: An engineer who designs, builds, and improves machines and mechanical systems.
Newton's first law of motion: An object at rest remains at rest, and an object in motion continues moving at a constant speed in a straight line unless acted on by an unbalanced force.
Newton's second law of motion: The acceleration of an object depends on the force applied to it and its mass.
Newton's third law of motion: For every action force, there is an equal and opposite reaction force.
Newton's laws of motion: Three laws that describe how forces affect the motion of objects.
Potential energy: Stored energy that an object has because of its position or condition.
Pull-back motor: A spring inside a toy vehicle that stores energy when the vehicle is pulled backward and makes it move forward when released.
Range: The total distance an object can travel.
Road surface: The material that forms the top layer of a road and comes into contact with vehicle tires.
Rotation: The movement of an object around a central point or axis.
Speed: How quickly an object moves from one place to another.

Terms - Continued

Structure: Something that is built from connected parts to support a load or serve a purpose.
Suspension bridge: A bridge in which the roadway is supported by cables hanging from tall towers.
Tension: A pulling force that stretches a material apart.
Traction: The grip between a vehicle's tires and the surface it is traveling on.
Truss: A framework of connected structural members, often arranged in triangles, that provides strength while using relatively little material.
Unbalanced force: A force that is not canceled by another force and causes an object to change its motion.
Variable: Something in an investigation that can be changed, measured, or controlled.
Weight: The force of gravity acting on an object.

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Thank you
End