SIMPLE AND COMPOUND MACHINES

STEM Activities for Use with the 2017 Hess Dump Truck and Loader

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The order of the activities may be changed if it is determined that it will create a more logical progression.

The 2017 Hess Dump Truck and Loader is available at www.hesstoytruck.com while supplies last.

The first Baylor College of Medicine/Hess Corporation STEM guide was published in 2016. It contains seven activities related to force, motion, friction and energy. The guide is freely available for download at http://www.bioedonline.org/lessons-and-more/focus-on-stem/force-motion-friction-and-energy/.

STEM is an acronym used to identify the academic subjects of science, technology, engineering and mathematics. By highlighting the inter-relatedness of these subjects, the STEM acronym encourages schools, districts and educators to integrate STEM content rather than teach each subject separately.

The STEM approach is important for workforce development and economic growth. Many careers are available in STEM-based fields, and forecasts indicate that in the future, there will be more STEM-based jobs than qualified workers to fill them.

For more information, visit http://changetheequation.org.

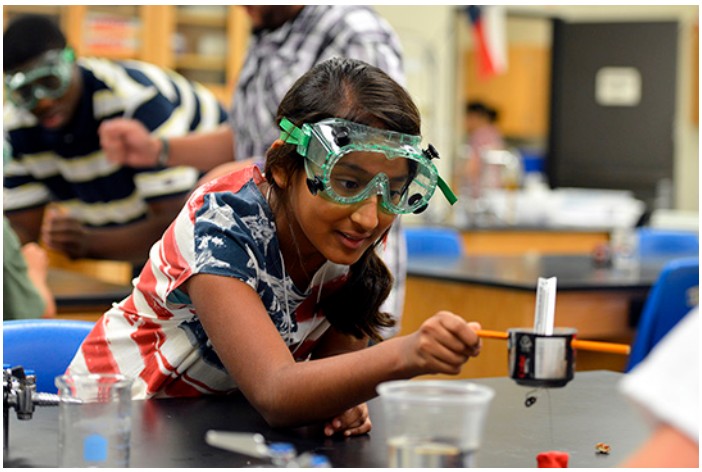
BAYLOR COLLEGE OF MEDICINE

Baylor College of Medicine, one of the country's top medical schools and research institutions, focuses on furthering its mission of excellence in the areas of education, research, healthcare and community service, both locally and globally. It is made up of the School of Medicine, the Graduate School of Biomedical Sciences, the School of Allied Health Sciences, and the National School of Tropical Medicine, the first in the Western Hemisphere devoted to neglected tropical disease.

Located in the heart of the Texas Medical Center, the world's largest health sciences complex, Baylor is surrounded by some of the leading institutions in healthcare. That concentration of expertise has helped support the development of collaborations that enrich every aspect of the College's mission.

With seven affiliated teaching hospitals, Baylor has a diversity of resources unparalleled at other academic health centers. In addition, the College maintains relationships with major academic partners and institutions such as the University of Houston, Rice University and NASA.

Baylor partners with community leaders to serve Houston, Texas, and the world through educational outreach programs, innovative healthcare delivery models and research focused on specific community needs. Its educational outreach programs reach students at all levels, from middle school through college, creating a pipeline of learners interested in science and medicine.



Baylor ranks first in Texas and 19th in the nation in funding to medical schools from the National Institutes of Health and first in the nation for genetics. It consistently ranks among the top medical schools in the nation for research and primary care by *U.S. News & World Report*.

The Center for Educational Outreach at Baylor College of Medicine offers a wide range of educational programs and resources that lead toward careers in medicine and the health sciences. These include teacher professional development programs and materials that improve the STEM content knowledge and skills of K–12 students. Educators earn continuing education credits 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. Online offerings include BioEd Online℠ and SuperSTAAR℠, which are dynamic web-based STEM teacher resources that provide coursework, streaming video presentations, teaching slide sets, inquiry-based classroom activities and complete teaching resources spanning preK–12. BioEd teacher resources and materials offer an integrated, hands-on approach to teaching STEM. Each inquiry-based unit is aligned with national and state science education standards.

HESS CORPORATION

Hess Corporation is a leading global independent energy company engaged in the exploration and production of crude oil and natural gas. Social Responsibility is integrated into the way we do business, enhancing our ability to be an effective and trusted energy partner and enabling us to meet the highest standards of corporate citizenship by creating a long-lasting, positive impact on the communities where we do business. Hess is committed to building trusted partnerships with governments, communities, employees, customers and stakeholders to develop programs that can make a measurable and sustainable difference. With over $175 million invested in social programs since 2011 we are helping to create an army of problem solvers that will overcome future complex challenges. Above all, we continue to be a company that cares about its people, its impact on the community, its reputation, and about doing the right thing.

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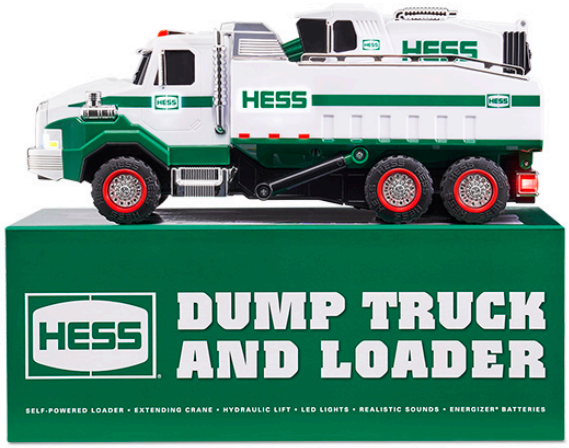
THE HESS TOY TRUCK STORY

The Hess company was founded in 1933 when Leon Hess bought a second-hand truck and started a business delivering fuel oil to homes in New Jersey. By the time Mr. Hess passed away in 1999, at the age of 85, Hess Corporation had grown into one of the world's largest energy companies including oil exploration, production, storage and over 1300 gas stations along the east coast. Not long after opening the first Hess branded gas station in 1960, 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, which has become a hallmark of the holiday season, with a new model released each year. Leon Hess wanted a toy truck made with outstanding craftsmanship and innovative use of electronics. And he wanted to offer it at a price families could afford with batteries included, a concept that endures to this day 53 years later, with the Hess Toy Truck remaining a beloved holiday tradition and among the largest selling toys in the country every year.



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HOW IT'S MADE

It takes a very long time (and a lot of STEM) to create a Hess Toy Truck. The process of developing the annual toy starts two to three years before the truck goes on sale. In some cases, a truck has taken as long as six years to go from concept to market. The drawings and feature concepts are reviewed, and the toys begin to evolve. The top two or three designs go to the next round, where they are transformed from drawings to handmade models. The models are evaluated for safety, functionality, playability, durability and value. Eventually, the new Hess Toy Truck is chosen. Each Hess toy is generally comprised of 75 to more than 100 small, hard plastic pieces. This year's Dump Truck and Loader in fact has 350 parts, the most ever. A tooling, or mold, for each piece must be cut to precise measurements. Once the toolings are made and tested, the pieces are produced and meticulously assembled. Then, as anyone who has unpacked a Hess Toy Truck knows, the final toy is placed—very carefully—into the toy box.

TOOLS TO TEACH STEM

Simple and compound machines are the basis of manufacturing, agriculture, transportation, communications, energy, space exploration, environmental management, and much more. They also are fundamental to many science, technology, engineering and mathematics (STEM) careers. In short, simple and compound machines are the backbone of our economy. Simple machines—levers, wheels and axles, pulleys, inclined planes, wedges, and screws—magnify force and produce motion. They enable us to perform difficult tasks quickly and efficiently. When two or more simple machines are combined, they become compound machines that enable us to perform complex tasks. Automobiles, trucks, trains, airplanes and other vehicles are compound machines consisting of thousands of parts. They transport people and goods, equipment and materials at speeds and in quantities and weights we could not manage on our own.

The 2017 Hess Truck consists of two vehicles: a dump truck and a loader. The Hess Dump Truck has realistic sound effects and lights controlled by buttons on the cab. One button triggers the lifting mechanism that tilts the bed upward to unload its cargo. The Truck also has a retractable ramp for off-loading and on-loading the Hess Loader, which is a continuous track-driven digging and loading vehicle. Switches enable the loader to travel forward and backward and also turn on its lights. The Loader has a rotatable cab and a retractable multi-jointed arm with a claw bucket.

Hess Trucks are much more than toys or 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. (To download the *Force, Motion, Friction and Energy* guide, visit http://www.bioedonline.org/lessons-and-more/focus-on-stem/force-motion-friction-and-energy/.)

Each activity in this guide uses the 2017 Hess Dump Truck and Loader to explore different aspects of simple and compound machines. The activities are introduced through a primer on simple and compound machines and an explanation of mechanical advantage. The activities can be used sequentially as a unit or inserted into an existing curriculum. While designed for middle grades (4–6), they can easily be adapted for upper and lower grades. The activities support the Three Dimensions of Science Learning in the Next Generation Science Standards (nextgenscience.org). Some activities include student pages that can be used for assessment or be placed in science notebooks. This guide and the 2017 Hess Dump Truck and Loader combine to provide a powerful STEM learning experience that is stimulating, enriching and just plain fun.

STEM CAREERS

Skilled workers for STEM and STEAM careers are always in demand, with jobs exceeding the number of prepared candidates. The 2017 Hess Dump Truck and Loader and the activities in this guide provide experiences that relate to many STEM fields such as the "Select Careers" listed below. These careers require competency in science, technology, engineering, mathematics and art.

SELECT CAREERS

- Architect
- Automotive Technologist
- Civil Engineer
- Community Planner
- Computer Developer
- Electrical Engineer
- Graphic Designer
- Mechanical Engineer
- Structural Engineer
- Technical Writer
- Toy Designer
- Transportation Engineer

THE 2017 HESS DUMP TRUCK AND LOADER

The 2017 Hess Dump Truck and Loader is a powerful partnership of heavy-duty earth movers. With over 30 brilliant LED lights plus realistic sounds, this oversized dump truck and 2-way motorized, track-driven loader are a versatile team, ready to tackle the toughest jobs!

The first ever Hess Dump Truck is boldly designed with a solid green base, white upper body, and green side stripes. The elongated hauling bed, on a dual-axle rear chassis, is custom-designed as a transport for its work partner, with an innovative fold-down tailgate that is also a hidden pull-out ramp for the Loader to drive right up into position! A cab-mounted button activates the hydraulic lift pistons (and associated sound), raising the bed into the dumping position. Four additional buttons trigger three more sounds (ignition, horn and backup) and flashes all of the brilliant lights. Chrome detailing includes front grille and bumpers, sun shield, cab steps, grab rails, and exhaust pipes.

The self-propelled, multi-direction powered Loader has a 270° rotating cab with a side-mounted extending boom featuring a jointed excavator arm and bucket combination that can bend and swivel in just about any direction. Two top-mounted switches activate the lights and the motorized tracks in either forward or reverse direction for ultimate maneuverability! Chrome accents include the exhaust pipes, side mirrors and grille.

Totaling 350 parts, this construction duo is the heaviest and most complex Hess Truck set ever!

DUMP TRUCK FEATURES

- 26 total lights that work in flash or steady mode, including super bright LED headlights
- Button activated hydraulic powered dumping action with sound effect
- 3 additional button-activated sound effects (ignition, horn, back-up)
- Fold down tailgate/pull-out ramp
- Free-rolling wheels

- Chrome accents
- 3 Energizer® AA batteries included

LOADER FEATURES

- Motorized track drive (forward and reverse)
- Independently rotating cab
- 8 lights that work in steady mode
- Extending boom and excavator arm with jointed, rotating bucket
- Chrome accents
- 2 Energizer® AA batteries included

MAINTENANCE TIPS

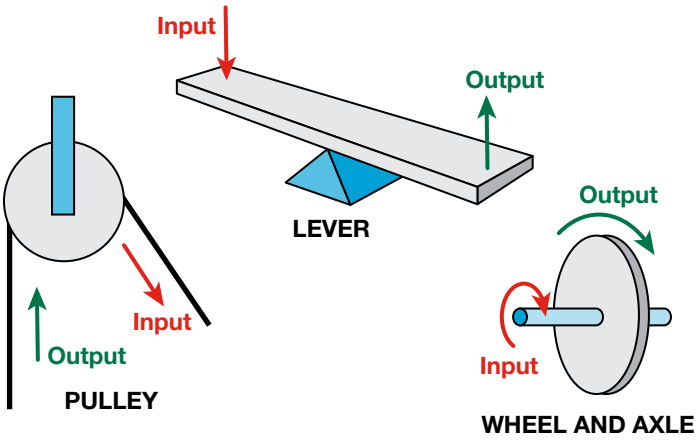
- Both the Hess Truck and Loader are powered by AA cells. The dump truck requires three AA cells; the loader needs two. A small Phillips® head screw driver is required to open the battery compartments for both vehicles. The dump truck battery compartment is located under a panel on the bottom of the truck frame, between the front and rear wheels. The battery compartment for the loader is located at the rear, behind a black box with two embossed "+" signs. Be sure to use new cells and orient them properly.
- While the Loader works well on a sand or soil surface, the rubber tracks will pick up sediment that could gradually make its way into the motor and drive mechanism. Therefore, it is recommended that the loader be run across sand paper, cloth, aluminum foil, and hard materials, such as pencils or small pebbles. For similar reasons, do not load the dump truck with soil or sand.
- Keep an eye on the rubber tracks of the Loaders. Some students may want to use them as wrist bands.

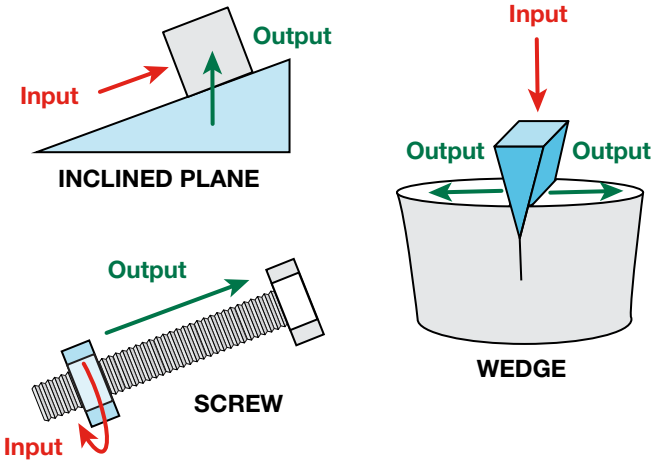
PRIMER: SIX SIMPLE MACHINES

The designs and mechanisms of the 2017 Hess Dump Truck and Loader are based on six categories of related devices known as simple machines. These devices were originally designated by scientists during the Renaissance (14th–17th centuries). The categories are listed below.

- Inclined Plane
- Lever
- Pulley
- Screw
- Wedge
- Wheel and Axle

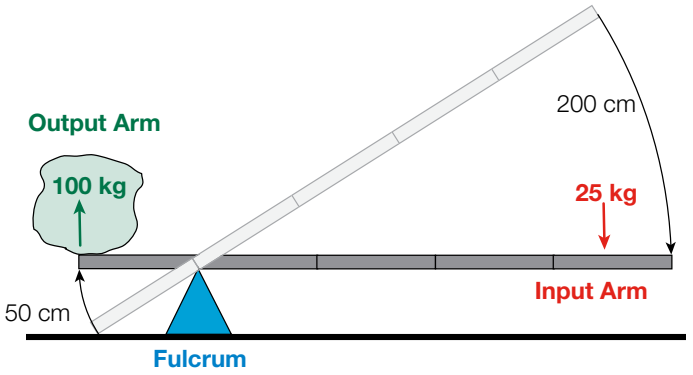
The lever, wheel and axle, and pulley involve circular motion to magnify force or change direction. The inclined plane and wedge involve straight motion to magnify force and change direction. The screw is an inclined plane wrapped around a shaft. It produces straight line motion when rotated.





Each simple machine magnifies force and/or changes the direction of motion via a concept known as mechanical advantage (MA), which refers to the amount of effort required to complete a job. Mechanical advantage applies to each of the six simple machines; how it is determined depends on the machine. For example, imagine that a large rock must be moved, but that it is too heavy to lift manually. In such a case, a lever consisting of a long beam or a pole can be used to lift the rock. Beneath the beam is a pivot, or fulcrum. When downward force is exerted on one end of the beam, the other end tilts upward, similar to the action of a seesaw. The mechanical advantage of this lever depends upon the placement of the fulcrum. If the fulcrum is placed in the middle of the beam, the mechanical advantage is 1:1. This means that a downward force on one end, called the input arm, will generate an equal upward force on the other, called the output arm. If the fulcrum is repositioned so that the input arm of the beam is twice as long as the output arm, the MA will be 2:1. In other words, the downward "input" force will be magnified two times on the other "output" end of the beam. However, the output arm in this example would travel only half as far as the output arm in the first example (with the fulcrum in the center of the beam). As they say, you don't get something for nothing.

The example below shows a lever with an MA of 4:1 (the input arm is four times longer than the output arm). A downward force of 25 kg exerted over a distance of 200 cm is met with an upward force of 100 kg over a distance of 50 cm.



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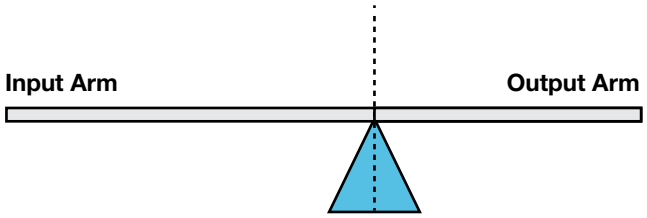
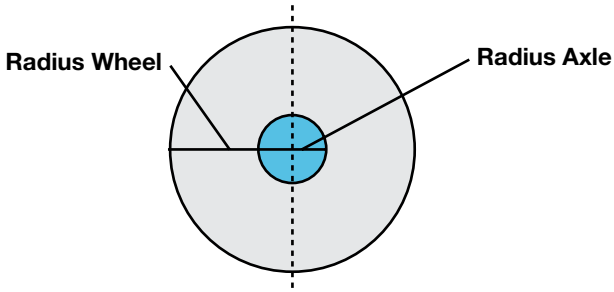
MECHANICAL ADVANTAGE

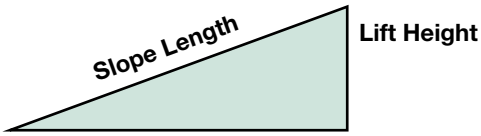
The concept of mechanical advantage applies to each of the six simple machines. How MA is determined depends upon the machine.



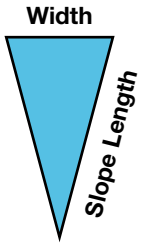
$$\textbf{Lever MA} = \frac{\text{Length of the input arm}}{\text{Length of the output arm}}$$



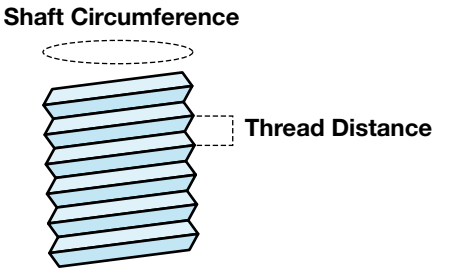
$$\textbf{Wheel and Axle MA} = \frac{\text{Radius of the wheel}}{\text{Radius of the axle}}$$



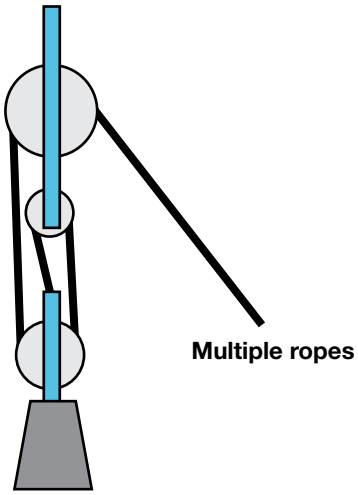
$$\textbf{Inclined Plane MA} = \frac{\text{Length of slope}}{\text{Height lifted}}$$



$$\textbf{Wedge MA} = \frac{\text{Length of slope}}{\text{Width of the wedge}}$$



$$\textbf{Screw MA} = \frac{\text{Circumference of screw shaft}}{\text{Distance between threads}}$$



Pulley MA = Number of ropes supporting the load

Mechanical engineers include one more factor—friction—when determining the mechanical advantage of a simple machine. The calculations above produce what is known as the ideal mechanical advantage (IMA): what a perfect machine would produce. The friction present in every system reduces the ideal mechanical advantage.

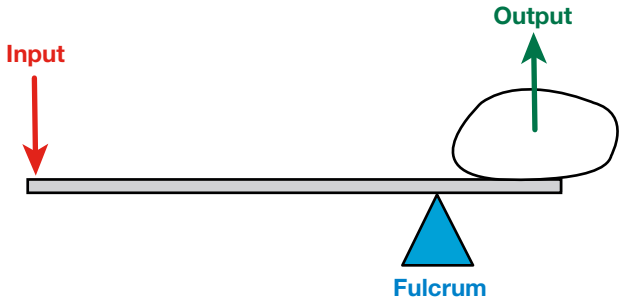
THREE CLASSES OF LEVERS

Levers take three different forms depending upon their use. The three forms of levers differ from each other in the

placement of the fulcrum (blue), the input force (red arrow), and the output force (green arrow). The directions of the arrows show which way the forces are exerted.

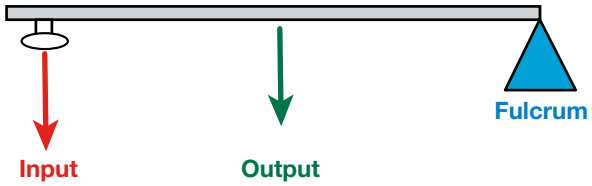
First Class Lever

Prying up a rock or tree stump, or a hammer prying up a nail. The fulcrum is the pivot point. The input force is provided by a downward push, and the load (rock) is lifted.



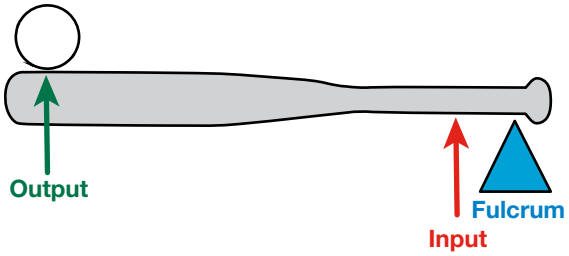
Second Class Lever

Opening a door. The doorknob is where the output force is exerted. The fulcrum is the hinge. The load to be moved is the door.



Third Class Lever

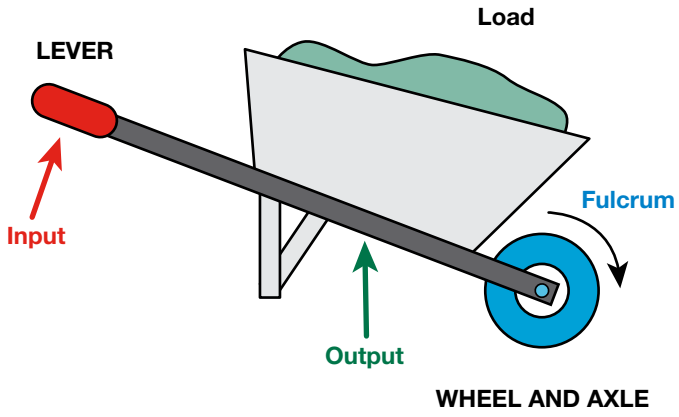
Swinging a baseball bat. The fulcrum is the shoulders of the batter. The batter's arm muscles swing the bat, providing the input force. The output force is transmitted to the baseball by the end of the bat.



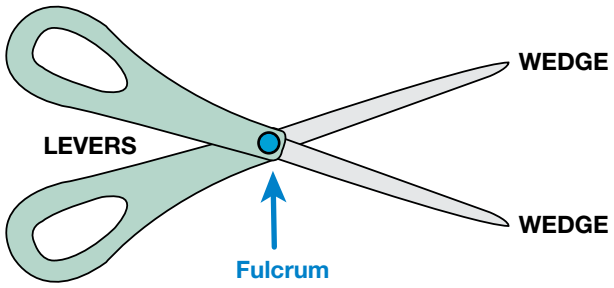
COMPOUND MACHINES

Most machines we see and use every day are compound machines, which consist of two or more simple machines, connected to serve a common purpose. The output force of one simple machine provides the input force to the next simple machine, and so on.

Compound machines can be as simple as a wheelbarrow, a garden or construction tool used to move gravel, dirt, bricks, etc. Wheelbarrows combine a lever with a wheel and axle. The lever enables a heavy load to be lifted. The wheel and axle serves as the lever's fulcrum and permits a load to be moved horizontally.



A pair of scissors consists of two levers, joined at a common fulcrum, and sharp wedge blades. The input force, bringing the handles together, is transmitted to the blades, thereby enabling them to cut paper or other material.



Another common compound machine, a bicycle, has pulleys connected with a chain loop. The rider inputs a force on the lever pedals, causing the rear pulley to turn the rear wheel and propel the bicycle forward.

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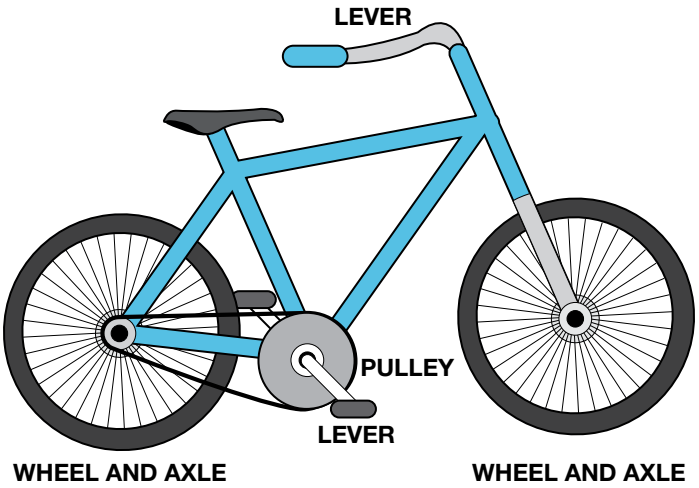


Most compound machines, especially in the transportation industry, are far more complex than bicycles or wheelbarrows. Planes, trains, cars, and trucks are compound machines built from thousands or tens of thousands of individual components, many of which are simple machines.

The 2017 Hess Dump Truck and Loader also are compound machines consisting of many connected simple machines. Of course, there are far fewer components in these toys than in the real-life vehicles on which they are based. Still, the Dump Truck and Loader are useful in helping students learn about the types and functions of simple machines.

1. HEAVY EQUIPMENT: SIMPLE MACHINES

The 2017 Hess Dump Truck and Loader are "work horse vehicles." Dump trucks and loaders are invaluable equipment for construction of large buildings, highways, airports, dams, and bridges; to the digging of pipelines and tunnels; and to surface mining operations and disaster assistance. These vehicles look (and are) complex, but each is basically just a large collection of simple machines. Because their parts work together to dig, load, and carry loads, the dump truck and loader are considered compound machines.

Before students begin to explore the capabilities of these toys, they should become familiar with the Dump Truck and Loader's mechanical components (simple machines). Each toy consists of at least five of the six categories of simple machines: lever, inclined plane, wheel and axle, wedge, pulley and screw. Not visible in the toys are gears, a variation of the wheel and axle. Gears are wheels that have teeth that mesh together with other gears so that when one rotates they all rotate to transmit force. Gears are part of the lift system of the Dump Truck bed and part of the drive system of the Loader.

THE QUESTION

How many simple machines can you find and identify in the 2017 Hess Dump Truck or Loader?

MATERIALS

Teacher

- "Teacher Answer Key"
- Digital projector or overhead projector and transparencies of "2017 Hess Dump Truck" and "2017 Hess Loader" pages

Per team of 2–4 students

- 2017 Hess Dump Truck and Loader (without the box; see "Management Tips")
- Demonstration examples of simple machines (e.g., pliers, scissors, manual can opener, hammer, jar with screw lid, wood screws, etc.)

Per student

- 2 copies of "Identify the Simple Machines" page
- Copy of "Six Simple Machines" and "Three Classes of Levers/About Gears" pages

Optional per team (see "Extensions," pages 2–3)

- Meter or yard stick
- 2 spring scales

MANAGEMENT TIPS

Before class, remove the 2017 Hess Dump Truck and Loader sets from the boxes. Store the boxes out of sight as information found on the boxes will be used in another activity.

The "Teacher Answer Key" (page 9) has been provided with answers to the student sheet, "Identify the Simple Machines." *Do not distribute to students*.

A detailed explanation of simple machines is found in "Primer: Six Simple Machines," (see pages viii–xi). Review the categories of simple machines, what they look like, and how they work.

Your students may not know the categories of simple machines, but they will have a practical knowledge of at least some of these machines and how they work. Begin a class discussion about common simple machines with which they have experience. For example, they will be familiar with jar lids (screw), wheelchair ramps outside buildings (inclined planes), bicycles and cars (wheels and

axles), doors and scissors (levers), etc. Two student pages provide pictures of the different kinds of simple machines and information on the classes of levers. These pages will help students as they try to identify the simple machines found in the 2017 Hess Dump Truck and Loader.

To avoid possible confusion about the three classes of levers, it will be useful to spend some time discussing them with the class. This will be particularly useful because students may not recognize that the lifter for the Dump Truck bed is a lever (second class). The fulcrum of the bed is located at the back of the truck. The input force comes from a simulated hydraulic ram. A ram is a shaft or rod that extends to move an object. The output force of the ram lifts the truck bed and the dumps the load being carried.

PROCEDURE

1. When you are comfortable that your students have a basic understanding of simple machines, introduce the class to the 2017 Hess Dump Truck and Loader. Create teams of 2–4 students and distribute one set of toy vehicles to each team (without the box). Allow time for students to become familiar with the toys and their controls.

2. Hold a class discussion and have each team, in turn, each describe one feature of the Dump Truck or Loader. Make a list of the features on the board. For example, the middle button on the truck releases the truck bed so that it dumps whatever it is carrying. The Loader travels forward and backward, and so on. After each team identifies a single observation, circle through the teams again so each can report a second observation. Continue updating the list on the board.

3. Distribute two copies of "Identify the Simple Machines," (page 4) to each student. Have teams work together, but make it clear that each student should complete his or her own diagram(s) for his/her science notebook. Students will make sketches of the side view of the Dump Truck. Then, they will label all of the simple machines they can identify on the truck by using the letter codes found on the student sheet. Students simply write the appropriate letter on their drawing in the location of each simple machine they identify. To assist in identifying simple machines, provide each student with a copy of "Six Simple Machines" and "Three Classes of Levers/About Gears" (pages 5–6) that illustrate different kinds of simple machines. Some items, such as screws, are not shown. Suggest to students that they identify simple machines they cannot see but know about—like a steering wheel—and the general area where the machines might be located. Each letter may be used more than once.

4. Repeat Step 3 with the Hess Loader. Alternately, to save time, students from each team can be assigned to sketch either the Dump Truck or Loader simultaneously.

5. When students have completed their sketches, project an image of the Hess Dump Truck and then the Hess Loader (pages 7–8) on a white or smart board. As part of class discussion, ask each team to identify one simple machine on the Truck, then the Loader. Repeat until all simple machines have been identified. Discuss the simple machines which may not be seen. Refer to the "Teacher Answer Key" (page 9) as a guide to make sure all simple machines are identified.

WRAP IT UP

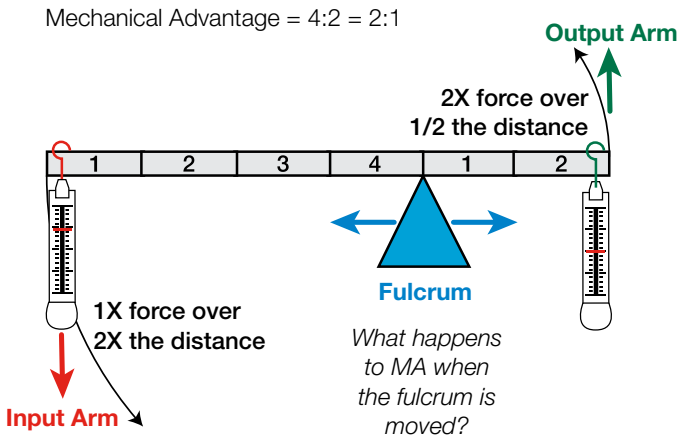
Have teams describe what they learned by closely examining the Hess Dump Truck and Loader. They should understand that devices like these consist of many simple machines working together to serve a purpose. Engines in real vehicles upon which the toys are based are powered typically by diesel fuel. The engines create a force, which then is transmitted and magnified by the simple machines and compound machines, which then dig, lift, carry, and dump loads far too heavy and time consuming for humans to manage without machines.

EXTENSIONS

- Investigate the mechanical advantage of a meter stick or yardstick lever. If you have spring scales (available from school science supply companies), have students investigate how the lifting (output) force of a lever varies

with the position of the fulcrum. For such an investigation, two spring scales will be needed—one to control and measure the input force and one to measure the output force. Refer to the diagram below for how to set up the investigation.

DETERMINING THE MECHANICAL ADVANTAGE OF A LEVER



The mechanical advantage of a lever equals the length of the force input arm divided by the length of the output arm. In this example the MA is 2:1 or 2. To measure the forces with the spring scales, one student pulls down on the scale attached to the input arm while another student holds the scale attached to the output arm. Reading the scales reveals the mechanical advantage of the lever.

Tip: To make this investigation work, the student pulling the input arm scale should do so gently because the force will be magnified on the output end. The student holding the output scale should exert enough downward force to keep the meter or yardstick level. This enables easy and accurate measurement of the input and output forces.

- For an additional extension, remove the spring scales and place a weight on the output end of the meter or yardstick. Have students feel for themselves the force necessary to lift the weight when the fulcrum is moved to different positions.

IDENTIFY THE SIMPLE MACHINES

Name _____

INSTRUCTIONS

1. Examine the vehicle you have been given and draw a picture of one side on the graph below. Write the name of the vehicle type in the box.
2. Use the codes (A–F) from the "Six Simple Machines" sheet to identify where each type of simple machine can be found. (Not all simple machines can be seen.)

Vehicle Type

SIX SIMPLE MACHINES

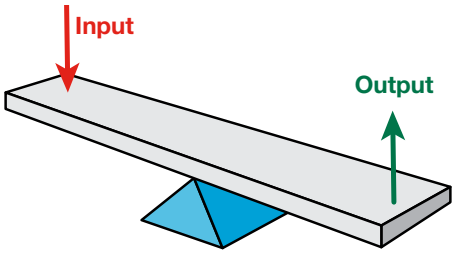
Name

INSTRUCTIONS

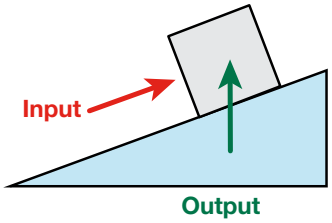
1. Use the diagrams and information below to code where and what type of small machines are located on the vehicles you drew on your "Identify the Simple Machines" sheets.

2. Try to think of one or more examples of where you have seen these machines before. List the examples in the spaces provided below, or on the back of this sheet.

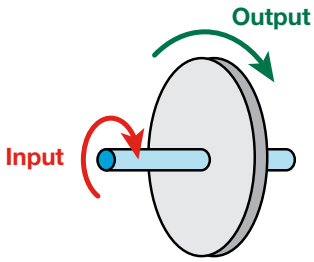
A LEVER



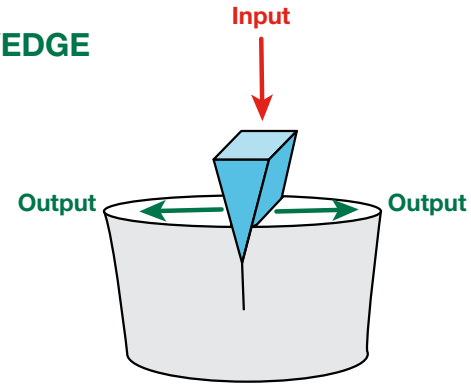
B INCLINED PLANE



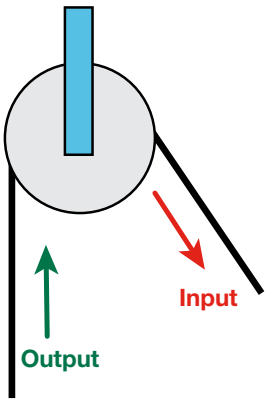
C WHEEL AND AXLE



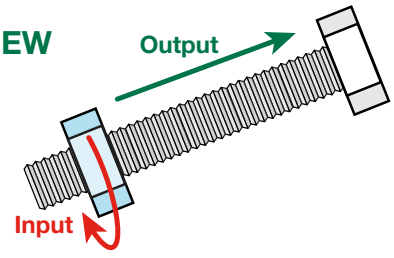
D WEDGE



E PULLEY



SCREW



THREE CLASSES OF LEVERS/ABOUT GEARS

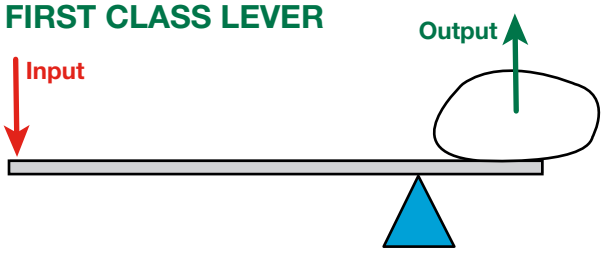
Name

INSTRUCTIONS

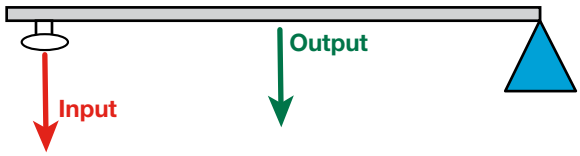
1. There are three different types of levers. The different kinds are called classes.

2. Look at the three types of levers shown to the right. Describe how each one is similar to the others, and how each one is different. Use the back of this sheet if you need more room.

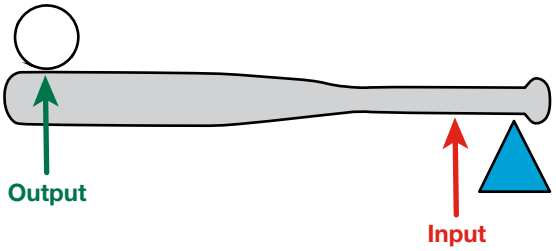
FIRST CLASS LEVER



SECOND CLASS LEVER



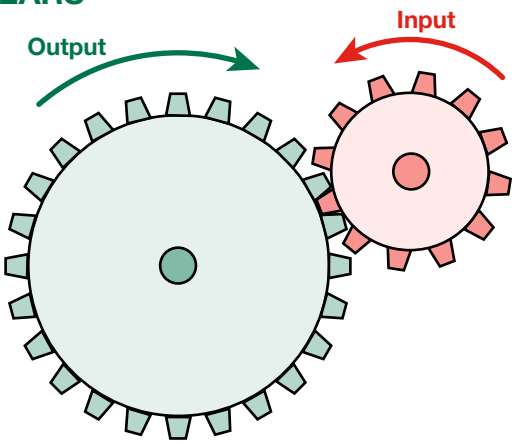
THIRD CLASS LEVER



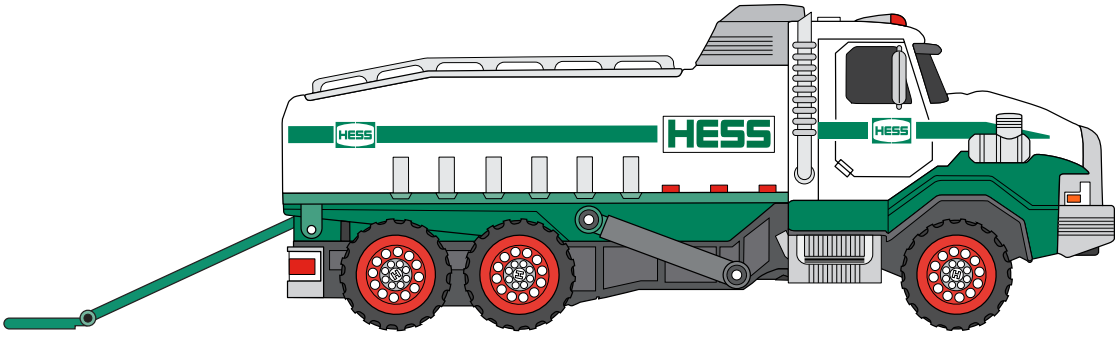
ABOUT GEARS

Gears are a form of a wheel and axle. Two or more gears touch each other and the teeth interlock. The teeth prevent the wheels from slipping against each other. In this example, when the large gear turns, the smaller gear turns in the opposite direction. In addition, the smaller gear has fewer teeth. It turns twice while the large gear turns just once. Where might gears be found in the Hess Dump Truck and Loader?

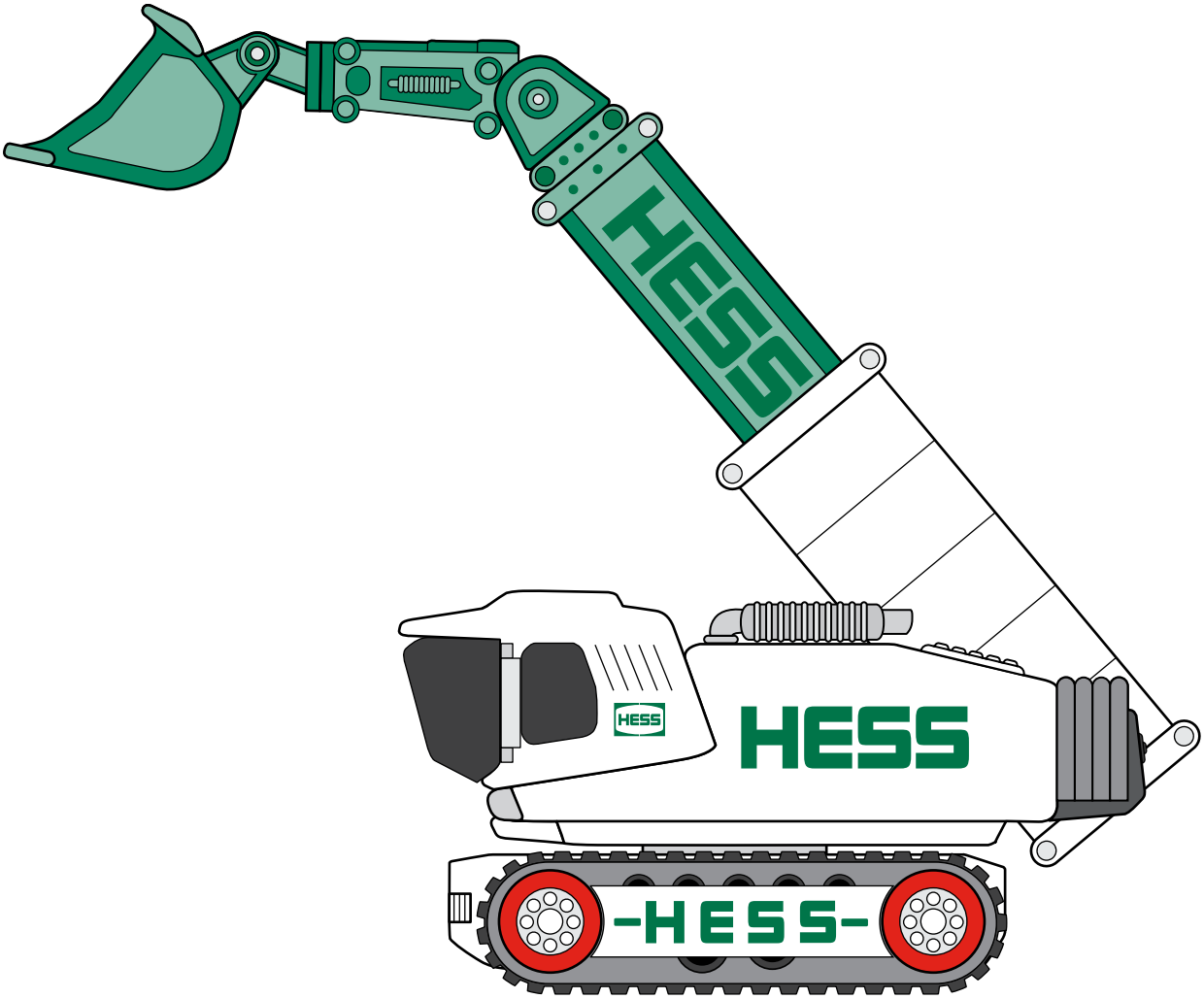
GEARS

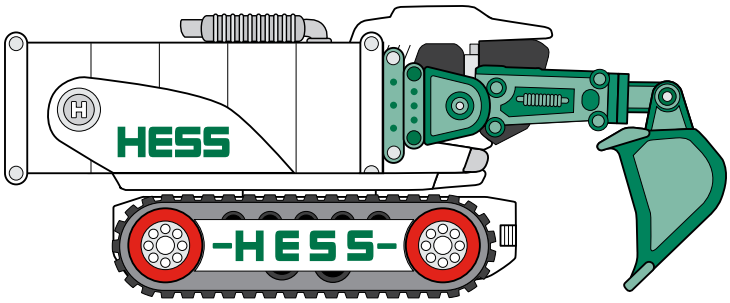


2017 HESS DUMP TRUCK



2017 HESS LOADER

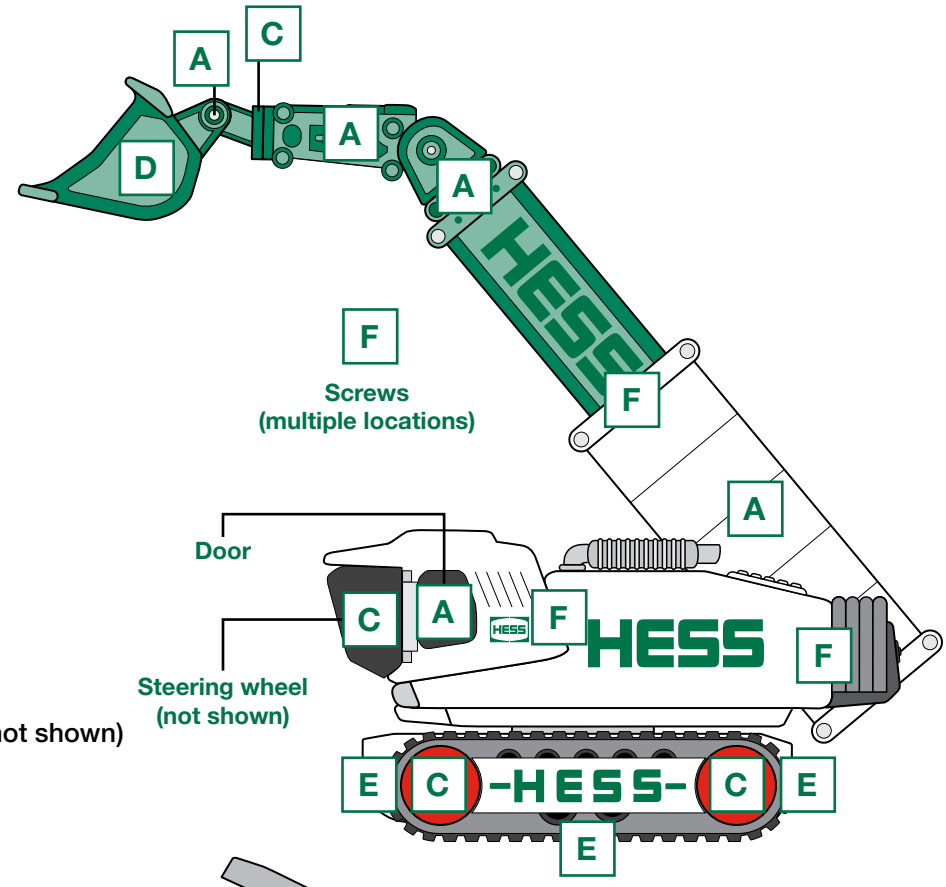


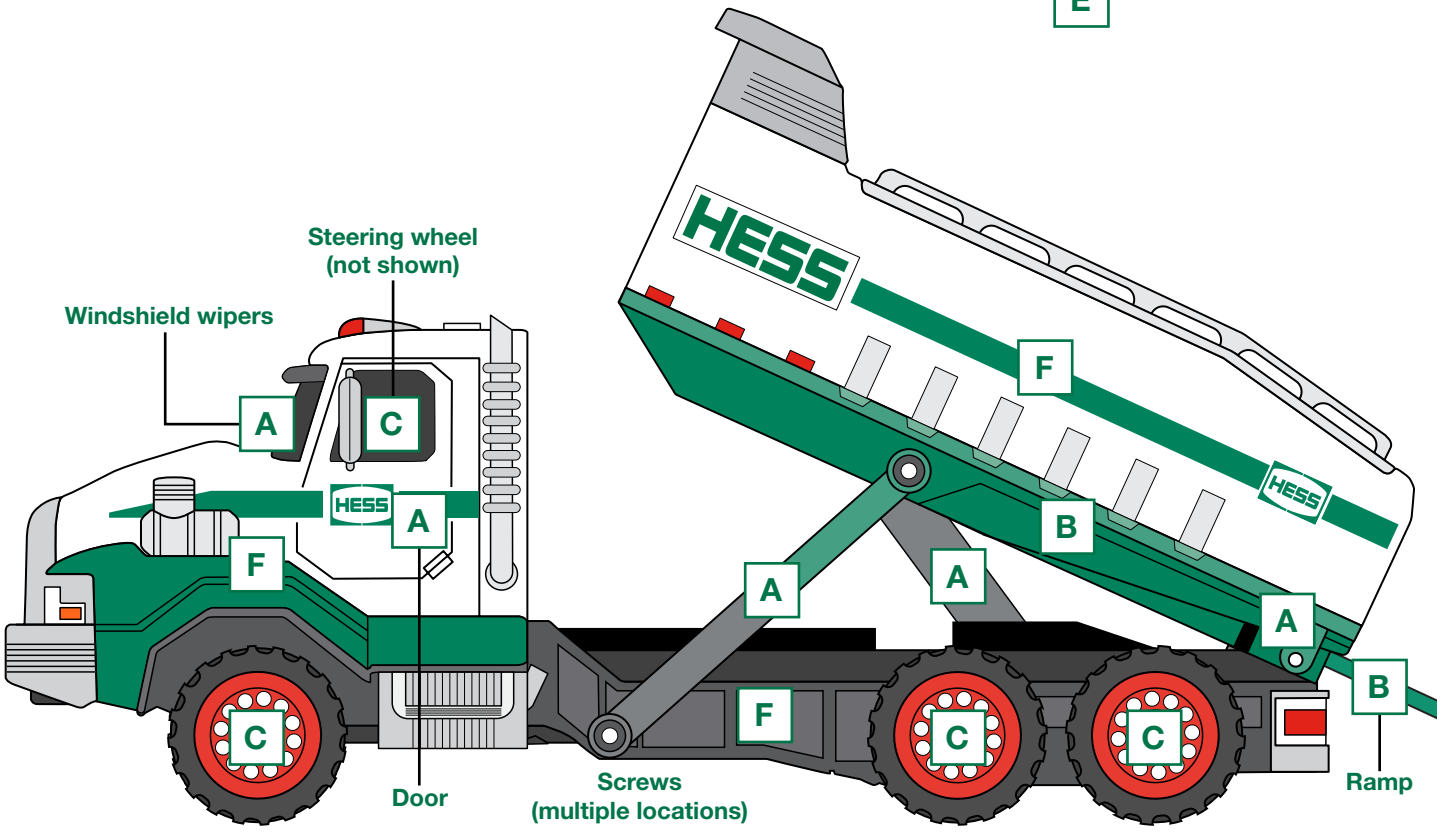


TEACHER ANSWER KEY

IDENTIFY SIMPLE MACHINES

- **A** Lever
- **B** Inclined Plane
- **C** Wheel and Axle
- **D** Wedge
- **E** Pulley
- **F** Screws (multiple locations; many not shown)

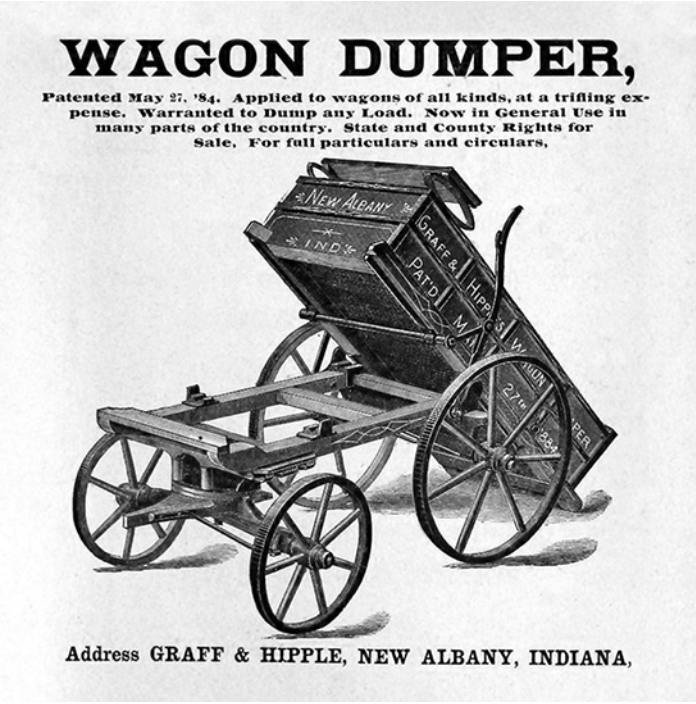




2. LIFTING FORCES

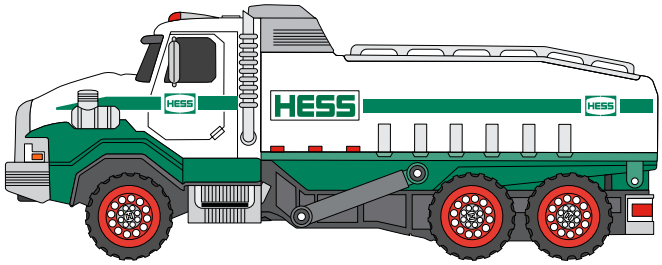
Dump trucks are most often used to transport loose material, such as gravel and sand. Dump trucks usually have an open-box bed that is hinged (fulcrum) at the rear. A hydraulic ram, a shaft that extends when pushed by a fluid, lifts the front to tip out the load through a rear door, which drops down.

The first dump trucks probably were invented in the late 19th Century for farm use. They consisted of some sort of horse or mule-drawn wagon with a large box in the back. The box could be tipped upward with a lever mechanism to dump the wagon load.



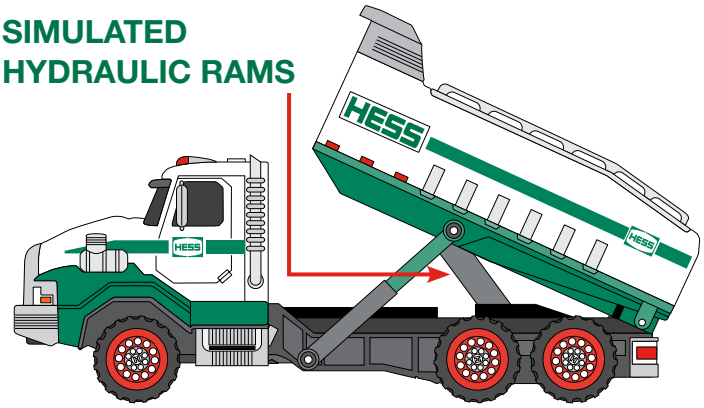
Modern dump trucks come in all shapes and sizes to meet specific needs. The 2017 Hess Dump Truck has been modified to transport the Loader. Its rear door not only drops down, but can be extended to become an inclined plane on which the Loader can drive off and onto the truck bed. The Loader, a tracked vehicle, has a multi-jointed arm with a bucket featuring a wedge-digging jaw. It can pick up gravel or other material and drop it into the bed of the Dump Truck. When full, the truck can carry its load to a chosen destination and dump it there. The dump truck then can return to the loader for another load or pick up the loader itself.

The 2017 Hess Dump Truck is based on six-wheel dump trucks in use today. If scaled up to actual size, it would be approximately six meters (20 feet) long and 2.5 meters (8 feet) wide. Its bed would be able to hold 9–11 cubic meters (12–14 cubic yards) of loose material. Depending upon the material, the load weight could be as much as 15 metric tons (17 short tons).



The hydraulic ram that lifts a real dump truck's bed consists of two cylinders and two pistons. A small piston pumps hydraulic fluid into the second cylinder which holds a larger piston. Like all fluids, hydraulic fluid is incompressible, so it causes the second piston to move. In the case of a

SIMULATED HYDRAULIC RAMS



real dump truck, the second piston extends and lifts the truck bed. The 2017 Hess Dump Truck uses a simulated hydraulic mechanism consisting of springs and gears. When the truck bed is horizontal, the springs are compressed. Pushing the appropriate button allows the bed to rise. The gears moderate the lifting force to smooth and slow the movement.

THE QUESTION

How do dump trucks unload their cargo?

MATERIALS

Per team of 2–4 students

- 2017 Hess Dump Truck
- 1/2-liter water bottle, filled and sealed
- Plastic syringes without needles [Size can vary but one syringe should be large (approximately 200 ml capacity) and the other small (approximately 50 ml capacity).] See "Management Tips" for sources.
- 1-meter piece of aquarium hose for each syringe
- Paper towels for water leakage and accidents

MANAGEMENT TIPS

Syringes are available from school science supply companies and may be available from local pharmacies and pet stores. Many schools already have syringes in their STEM supplies. Pair one small and one large syringe with a one-meter length of aquarium tubing for each set up. The tubing will fit snugly over the syringe tip. Permit students to investigate what happens when the syringes are connected with just air inside. Have them see what happens one syringe piston is depressed. This makes a pneumatic system. When the water is added, it becomes a hydraulic system.

If using this activity with younger students, consider preassembling the syringes. Make up some with air and some with water (see "Hydraulic System Model," page 12).

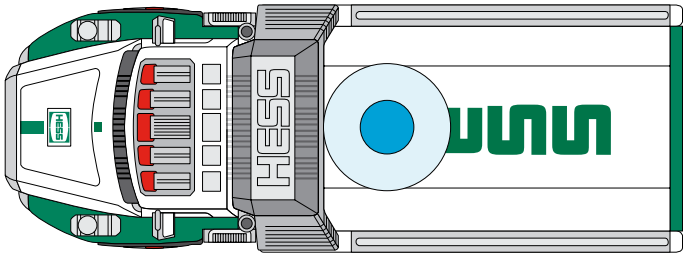
PROCEDURE

Part 1. Lifting Loads

1. Have students work together in teams of 2–4 to familiarize themselves with the dump truck mechanism. Challenge them to determine what parts of the toy cause the bed of the truck to lift. Have teams write a short description of the mechanism and how it works. Remind them to incorporate in their description what they learned from the previous activity about simple machines.

2. Discuss students' conclusions about how the truck lifts its bed (the bed is lifted by the twin simulated hydraulic rams identified above left, and a mechanism within the housing between the rear wheels which remains hidden from students). The mechanism is a combination of a spring and gears. When the bed is down and locked, potential energy is stored in the springs. When the latch is released, the potential energy converts into kinetic energy, which extends the white pistons from the black cylinders. The white pistons, rams, lift the truck bed.

3. Have each student team place a filled and sealed half-liter (500 ml) water bottle in the bed of the truck. The bottle should be centered on the large "H" in the HESS name. Ask students, *Is the truck bed lifting system able to dump the bottle?*



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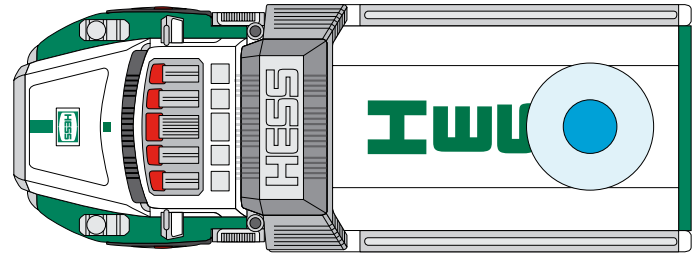


Have students try again with the bottle centered over the last "S" in the HESS name. Ask, *Can the truck dump the bottle now?* Follow with, *Why is the truck able to dump its load when the bottle is placed over the last "S" but not when the load is over the "H"?* (Remind students of mechanical advantage in levers. Moving the weight nearer to the fulcrum magnifies the lifting force.)

Part 2. Modeling Pneumatic and Hydraulic Systems

1. Provide each team with a piece of aquarium tubing and two plastic syringes of different diameters.

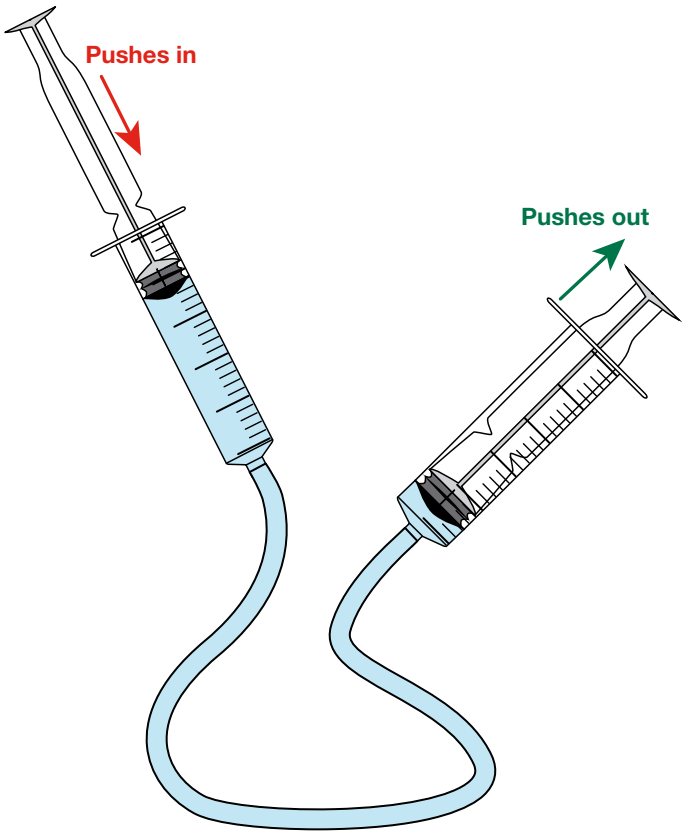
2. Instruct teams to start by connecting one end of the tubing to the larger syringe. The plunger of this syringe should be positioned all the way down its cylinder. Connect the other end of tubing to the smaller syringe, with the plunger pulled to the top of its cylinder. When complete, the two syringes should be connected by the tubing.

3. When the syringes are properly connected, have teams push the small syringe plunger all the way into its cylinder. Ask students, *What happens to the plunger on the large syringe? Do they move the same amount?* Have teams push the larger plunger back in. Ask, *What happens to the small syringe plunger? Which plunger moves the greatest distance?*

4. Discuss team observations. Student responses might include (1) the big piston moves out, (2) there is a slight delay before the big piston moves, and (3) the big piston doesn't move as far as the small piston does, among others.

5. Explain to students that they are working with a pneumatic (air-driven) system. Because gas is compressible, there is a slight delay in the movement of the big plunger when the small syringe is depressed. Pressure inside the cylinder must exceed the friction of the rubber end of the plunger with the cylinder wall. The larger syringe plunger moves a shorter distance than the plunger of the smaller syringe because of a size (cylinder radius) differential. The bigger the large syringe is compared to the small syringe, the less its plunger moves, but the greater the force.

HYDRAULIC SYSTEM MODEL



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6. Have students take the following steps to fill their systems with water. Remove the plungers from both syringes. Fill the larger syringe with water and use it to flush out air from the tubing and the small syringe by inserting the plunger and pushing it all the way to the bottom. Be careful—water will squirt out from the other end. Insert the plunger into the smaller syringe and move it to the upper mark on the scale. The system is ready for investigation.

   Tip: The addition of water to the syringes should be done over a sink. To avoid potential accidents, it might be advisable to add the water yourself. Consider conducting Steps 7 and 8 the day after Steps 1–6 and adding the water before class.

7. Repeat Step 3, now with water in the system (see illustration, page 12). This is a hydraulic system and students will note that it responds instantly to any adjustment of one or the other plunger because the water is incompressible. Have students observe how far the plunger of each syringe moves when the opposite one is pushed in.

8. Discuss student team observations.

WRAP IT UP

Review how the truck bed is lifted. Remind students that mechanical advantage applies to hydraulic pistons as it does to all simple machines. The small piston exerts a small force over a long distance. The force transferred to the larger cylinder is magnified, but the piston only moves a short distance. Actual hydraulic systems have reservoirs so that pumps can add more and more fluid, thus extending the distance the ram can travel.

Discuss other applications of hydraulic rams: car repair shops, car brake systems, large presses, etc.

EXTENSIONS

- The simulated hydraulic pistons under the center of the Hess Dump Truck bed lift the bed to unload the cargo. Two black and green struts move when the bed lifts. The struts are located on opposite sides of the truck bed, attached to the truck frame behind the cab. Ask your students to investigate these struts or rods and determine their purpose. (Slots in the black portions of the struts face each other. The green extensions have small pins that protrude through the slots. These pins serve as stoppers to prevent the truck bed from opening too far.)
- Ask students, *Besides lifting the beds on real dump trucks, what other uses might there be for hydraulic pistons?* Challenge student teams to invent something that is operated by the syringes used in Part Two of this activity. They should make sketches of their idea and then build a prototype.
- Mathematics: The force transferred through a hydraulic system is related to the diameters of the smaller and larger cylinders. The following equation enables calculation of the force produced.

$$\frac{F_{large}}{A_{large}} = \frac{F_{small}}{A_{small}}$$

F_{large}	Force transmitted through large syringe
F_{small}	Force transmitted through small syringe
A_{large}	Cross section area of large syringe
A_{small}	Cross section area of small syringe

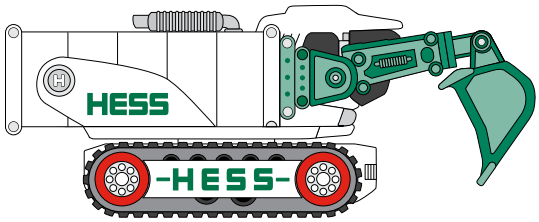
3. TRACTION AND THE CENTER OF GRAVITY

The 2017 Hess Loader is a digging and loading machine for the Dump Truck. Rather than large wheels with thick treads, the Loader features continuous tracks for gripping the ground.

Continuous tracks—also known as tank treads or caterpillar tracks—are bands, typically made of linked metal treads, each driven by two or more wheels. The tracks greatly enlarge the surface area of the vehicle in contact with the ground, thereby distributing the vehicle's weight over a large area. This feature makes it easier for the vehicle to operate over soft ground without becoming stuck.

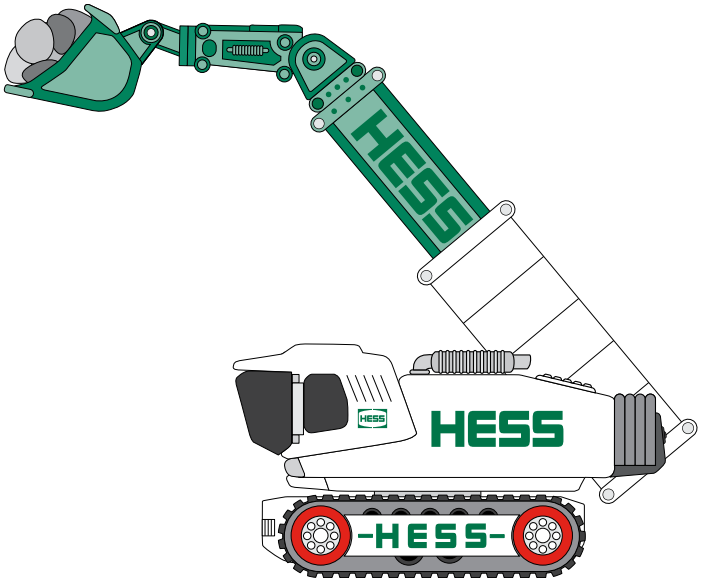
Continuous tracks generally have large treads to take a big bite out of the soil. They produce a large propelling force for the vehicle in digging and plowing operations, but may limit where the vehicle can be used. For example, deep steel tracks can damage paved roads.

A vehicle with continuous tracks has great maneuvering capabilities. The driver can move it forward or backward and turn to the right or left. Turning involves slowing one track (on the side of the vehicle to which the driver wishes to turn) while the other track keeps going. Extreme maneuvering is possible by moving one track forward while the other moves



backward. This enables the vehicle to turn in circles while standing in one place.

One important consideration while operating a Loader is its center of gravity, or the average point of all of an object's weight. In other words, the center of gravity is an imaginary point where all of the weight of an object is concentrated so that if you supported the object at that point, it would be perfectly balanced. For example, if you place a yardstick over an outstretched finger, it will balance over its midpoint (its center of gravity). Why is this important to the Loader operator? The Loader is a complex shape but it has a center of gravity. If the operator maneuvers the Loader to a point where its center of gravity is not above the tracks, the Loader will tip over. It might seem that this problem would be avoided by not trying to climb too steep a hill. However, it is not that simple.



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The Loader arm can be extended and moved into different positions. The center of gravity moves accordingly. The weight of the load in the bucket also will adjust the location of the center of gravity. It is easy to observe how this works by standing on one foot with arms at the side and a heavy book or some other weight in one hand. Keep your other foot next to your leg. Your center of gravity is directly above your foot and you remain balanced. However, extend the arm with the weight outward and the center of gravity shifts slightly so that it is no longer over your foot. You begin to fall to the side.

To avoid accidents, it is critical for operators to understand these concepts and how working the arm can change the position of gravity.

THE QUESTION

Why does the 2017 Hess Loader have continuous tracks instead of wheels with big treads for traction?

MATERIALS

Per team of 2–4 students

- 2017 Hess Loader
- 4-meter length of aluminum foil (heavy duty works best)
- Heavy book
- Masking tape
- Smooth wooden board, approximately 4 ft x 8 in. x 1 in. (122 cm x 20 cm x 2.5 cm), available from a hardware or home improvement store
- Stopwatch or smart phone timer
- Weights for the digging bucket (e.g., coins, metal washers, aquarium gravel)

MANAGEMENT TIPS

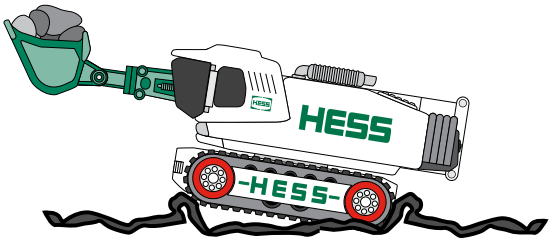
The twin rubber continuous tracks are easily removed. Remind students to make sure both tracks are on each Loader at the end of the class period.

PROCEDURE

1. Permit student teams to explore the 2017 Hess Loaders to determine their function and operating controls. The Loader's tracks permit it to move forward or backward only. The Loader cannot turn or revolve in place. However, the Loader can pivot on its base, enabling the Loader to travel sideways—but only along the original direction of the tracks.

2. Have teams place various objects (e.g., pencils, notebooks, cloth, etc.), in front of the Loader to test its traction while attempting get over them. Ask students, *Is there a limit to the Loader's traction and climbing capacity?* Discuss student team observations.

3. Invite a volunteer to stand on one foot with the other foot next to his or her leg. Hand the student a heavy book and have the student hold arms down. The student's center of gravity will be directly above the foot on the floor and the student will remain balanced. Then have the student extend the arm with the book. The center of gravity will shift slightly in the direction of the arm and book and no longer be directly above the foot on the floor. The student will start to fall over.



4. **Rough Road.** Prepare an aluminum foil test track for the Loader. Pull out about four meters of foil. Purposely pinch and wrinkle the full length of the foil crossways with many stout ridges and bumps about 1–2 cm high. Use masking tape to anchor the corners of the foil to the floor or to a lab tabletop.

5. Have one team at a time place its Loader just behind the front edge of the foil (the starting line). Have each team test how well its Loader travels the length of the aluminum foil test track. After all teams have made their first runs, have them place items in the upturned digging bucket as shown above. Ask students, *Will the Loader maintain its center of gravity and remain upright? Will it tip over? Will it spill its load? Also have teams try tilting*

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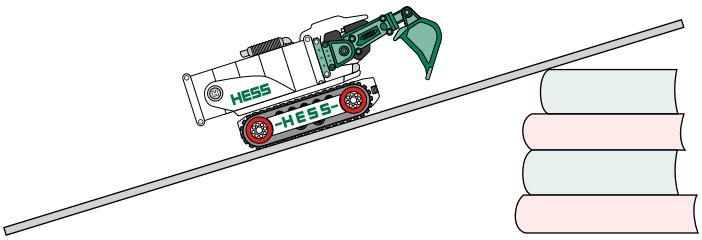


the loaded arm upward at different angles to test its effect on the Loader's balance.

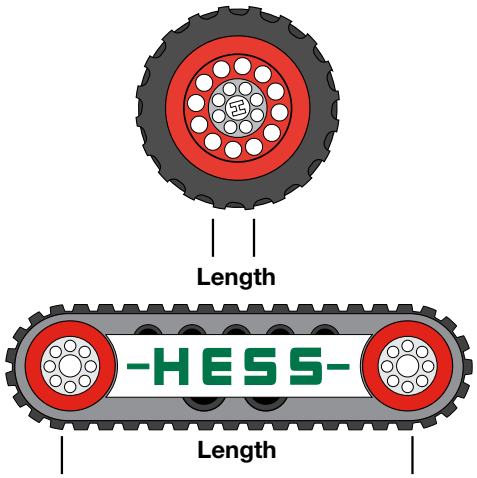
6. **Climbing Slopes.** Prepare a second test for the Loaders. Elevate one end of the board with a box or stack of books. The object is to determine the steepest angle (inclined plane) the Loaders can climb. Center of gravity will be an important consideration in this test. Ask students, *What is the best position for the Loader arm?* Through trial and error, determine the steepest angle that the Loader can climb without tipping over. Can the angle be increased if the digging Loader carries a heavy load? Ask, *Will the extra mass affect the Loader's ability to climb?*

WRAP IT UP

- Have students describe the advantages and disadvantages of continuous tracks.
  - **Positive:** Increased traction and maneuverability, ability to operate over soft surfaces.
  - **Negative:** Slow moving, not suitable for operation on paved surfaces.
- Discuss each team's strategies for enabling the Loader to traverse the aluminum foil track in the fastest time (where to place the Loader, aiming, etc.).
- Review the concept of center of gravity. Ask students, *How does the position of the Loader's arm affect its ability to remain upright on a steep hill?*

EXTENSIONS

- Have teams compare the contact area of the Dump Truck's six wheels to that of the Loader's tracks. They will need a centimeter ruler. To calculate the contact area, have teams follow the steps below.
  - Observe the Dump Truck and identify how much of each wheel actually touches the table surface (approximately two treads per wheel). Teams should measure the span



of the two treads and the width of the wheel. Multiplying these numbers will yield the contact area of one wheel.
  - Multiply that number by six (six wheels) to calculate surface contact area for the entire truck.
  - The Loader tracks make contact directly beneath the center of each red wheel. Measure this length and multiply that number by the width of the track. (In actual use, the treads sink a short distance into the surface so that the entire bottom of the track contacts the surface.)
  - Multiply that number by two to calculate the surface contact area for both tracks.
- Ask students, *Which vehicle has the most surface contact?* Discuss with the class. The pressure each vehicle exerts on the surface can be determined by weighing the vehicles on a balance or kitchen scale. Divide the weight in grams by the surface contact area for each vehicle to determine how many grams press down on each square centimeter of the surface. Ask, *Does this information help to explain why the Dump Truck can get stuck in soft surfaces while the Loader does not?*

Approximate Answers

Truck wheel surface contact area ~ 1.5 cm^2
Total truck wheel surface contact area ~ 9 cm^2
Truck weight ~ 846 gm
Truck surface pressure ~ 94 gm/cm^2

Loader track surface contact area ~ 14 cm^2
Total Loader track surface contact area ~ 28 cm^2
Loader weight - 363 gm
Loader surface pressure ~ 13 gm/cm^2

4. DEGREES OF FREEDOM

The Hess Loader is based on real vehicles that have a multi-articulated arm with a digging bucket at its end. It is similar to, but more advanced than traditional backhoes and excavators.

Backhoes usually have wheels with a digging arm on one end and a scoop on the other. The digging arm can swing from side to side. It extends "feet" to keep upright (maintain its center of gravity) when digging (see white circle on the photo below). The backhoe shown below can move its digging arm up and down and swing right and left. It has an elbow and a wrist joint for tilting the bucket.

© Dmitry Kalinovsky.

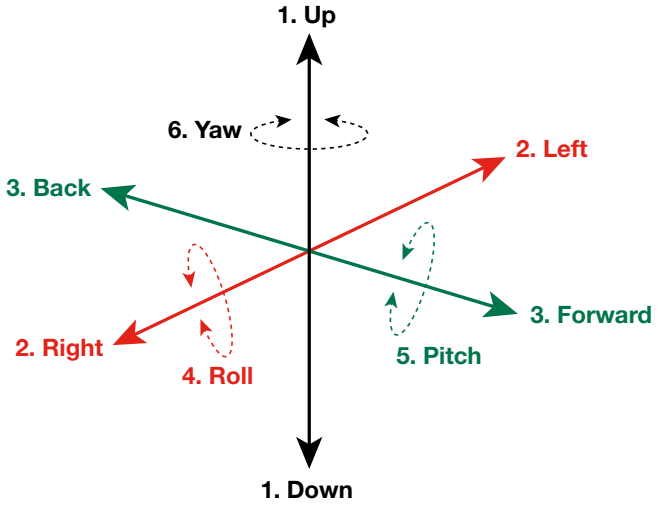
Excavators are usually larger than backhoes and are used for bigger jobs. They are propelled by continuous tracks but can have wheels instead. Their digging arm joints are similar to the joints on the arms of backhoes. However, excavator arms are more versatile because they are mounted to a chassis or cab that can rotate 360 degrees.

© Budabar.

© Hess Corporation.

The arm of the Hess Loader also has multiple joints. Its arm can be lengthened and its bucket can both tilt and rotate 270 degrees. However, the toy does not have true hydraulic rams that would operate a real full-size loader arm.

Movements of the Hess Loader arm can be described as "degrees of freedom" a phrase often used to describe the functionality of robot arms. Degrees of freedom refer to the number of independent movements an object is able to make. For a robot arm, degrees of freedom include all different directions the arm can move. No system can



move in more than six different directions: (1) up/down, (2) right/left, (3) forward/back, and the rotating motions of (4) roll, (5) pitch and (6) yaw. Each movement is a degree of freedom. If a joint on a robot arm can move up and down, swing side to side, and rotate, the joint is said to have three degrees of freedom.

In this activity, students will examine the 2017 Hess Loader to determine how many degrees of freedom, or independent movements it has. The degrees of freedom include not just the movement capabilities of the arm but also the cab and continuous track base.

THE QUESTION

How many degrees of freedom does the Hess Loader have?

MATERIALS

Teacher

- "Teacher Answer Key"

Per team of 2–4 students

- 2017 Hess Loader

Per student

- Copy of "Find the Degrees of Freedom" page

PROCEDURE

1. Obtain a picture or video of a working backhoe or excavator from the Internet. Have students compare the picture/video of the backhoe to their Hess Loaders. Ask, *How are they similar? How are they different?* Possible answers are given below.
   - Both have digging arms.
   - Both have cabs for their operators.
   - The Hess arm has more joints.
   - The backhoe can have "feet" that extend.
   - The Hess Loader has continuous tracks and the backhoe and excavator may have continuous tracks or wheels.

2. Continue the discussion by focusing on the arm of the backhoe or excavator. If visible, point out the hydraulic rams. Remind students that the Hess Truck has simulated hydraulic rams to lift the truck bed. Discuss why hydraulic rams are used for the loader, and backhoe and excavator arms. Point out that hydraulic rams can provide a great force for digging and lifting.

3. Introduce the phrase "degree of freedom" (DOF). Call for a volunteer to stand in front of the class and focus students' attention on the volunteer's arm. Compare it to the arms on the loader and backhoe. Have the student swing her or his arm forward and back from the shoulder to demonstrate one degree of freedom. Then, have the student lift her or his arm sideways until it is extended straight out. Raising the arm is a second DOF for the shoulder. Swinging the extended arm forward and back is the third DOF. While the arm is still held straight out from the shoulder, have the student bend her or his elbow to demonstrate DOF number 4. Next, have the student bend her or his wrist (DOF 5) and rotate the wrist (DOF 6). The multi-jointed fingers on the student's hand add another 3 DOF each. Remind students that each independent movement represents one degree of freedom.

4. Have teams work together to identify and count all degrees of freedom on their loaders. Make sure students understand that a DOF represents a single motion, such as the joint that enables the Loader arm to extend or retract, the digging bucket to rotate, or the Loader to move forward or back. Every team member should complete a student page for their science notebooks. Ask, *How many degrees of freedom does the Hess Loader have?* (8 DOF)

Continued

WRAP IT UP

Ask students, *Did any team count 12 DOF, 11 DOF, 10 DOF?* Refer to the "Teacher Answer Key" for the actual number of DOF for the loader. Ask, *Why does the Loader have so many degrees of freedom?* The answer is versatility. The arm can reach out in any direction, move up or down, and rotate the digging bucket. This versatility enables the arm to dig and load quickly under any condition without having to continually reposition the vehicle to complete a task.

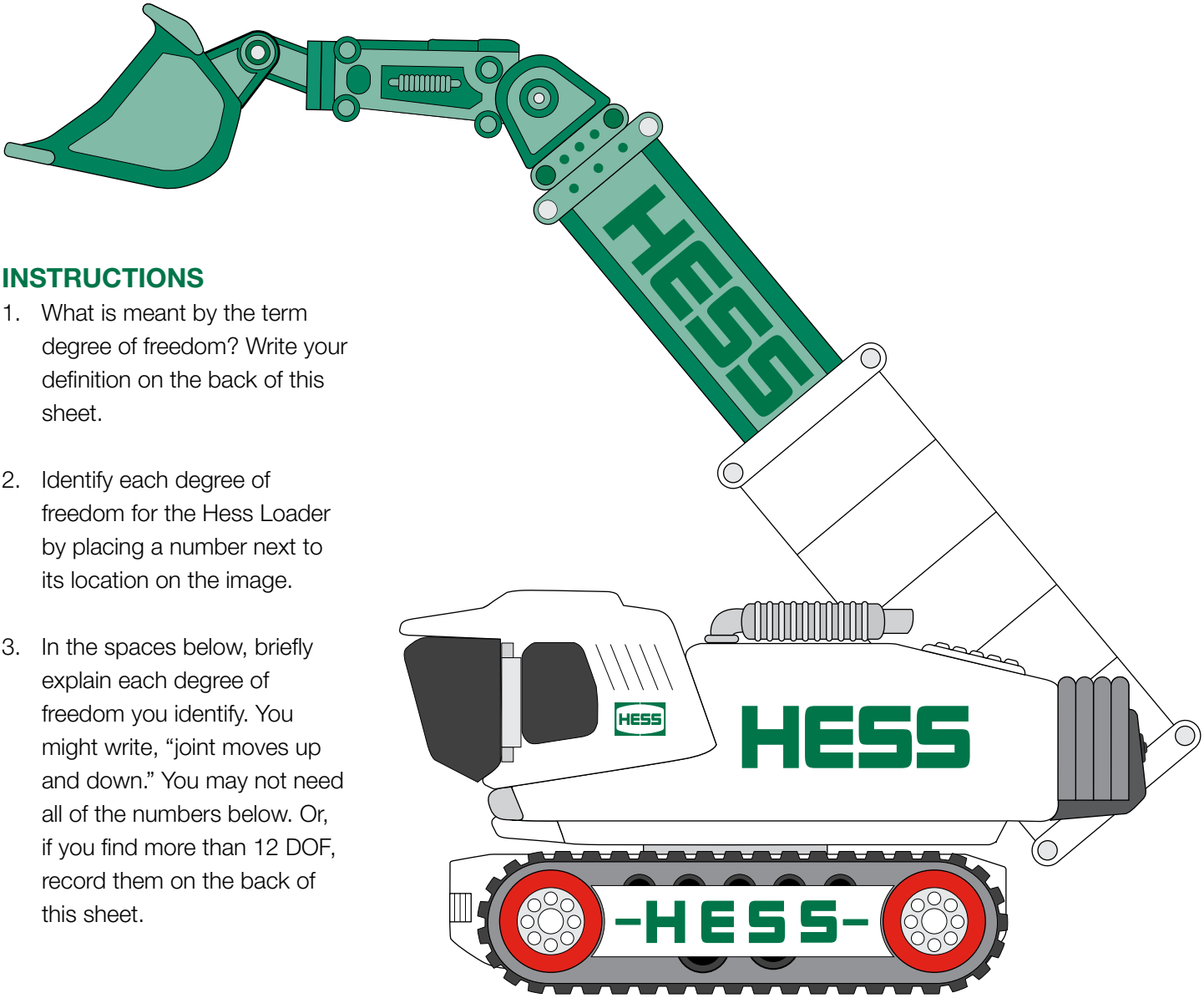
To demonstrate, hold out your arm, keeping the elbow stiff. Try to pick up a pencil that is too close to you. Because your hand extends beyond the pencil, you cannot grasp it. Try again, but this time, permit your elbow to bend. Show that 2 DOF enables you to pick the pencil. Besides bending at the elbow, the pencil also can be grasped if you step backward a bit. This simulates the DOF of the Loader tracks. The Loader's 8 DOF permits it to handle almost any work situation.

EXTENSION

Challenge teams to investigate the area that the Loader's arm can reach when it is stopped in its tracks. When the loader is stationary, its arm can reach an area resembling a pie with a 1/4-wedge removed. Ask students, *Could the Loader be used for other things besides digging?*

FIND THE DEGREES OF FREEDOM

Name _____



INSTRUCTIONS

1. What is meant by the term degree of freedom? Write your definition on the back of this sheet.

2. Identify each degree of freedom for the Hess Loader by placing a number next to its location on the image.

3. In the spaces below, briefly explain each degree of freedom you identify. You might write, "joint moves up and down." You may not need all of the numbers below. Or, if you find more than 12 DOF, record them on the back of this sheet.

1 _____

2 _____

3 _____

4 _____

5 _____

6 _____

7 _____

8 _____

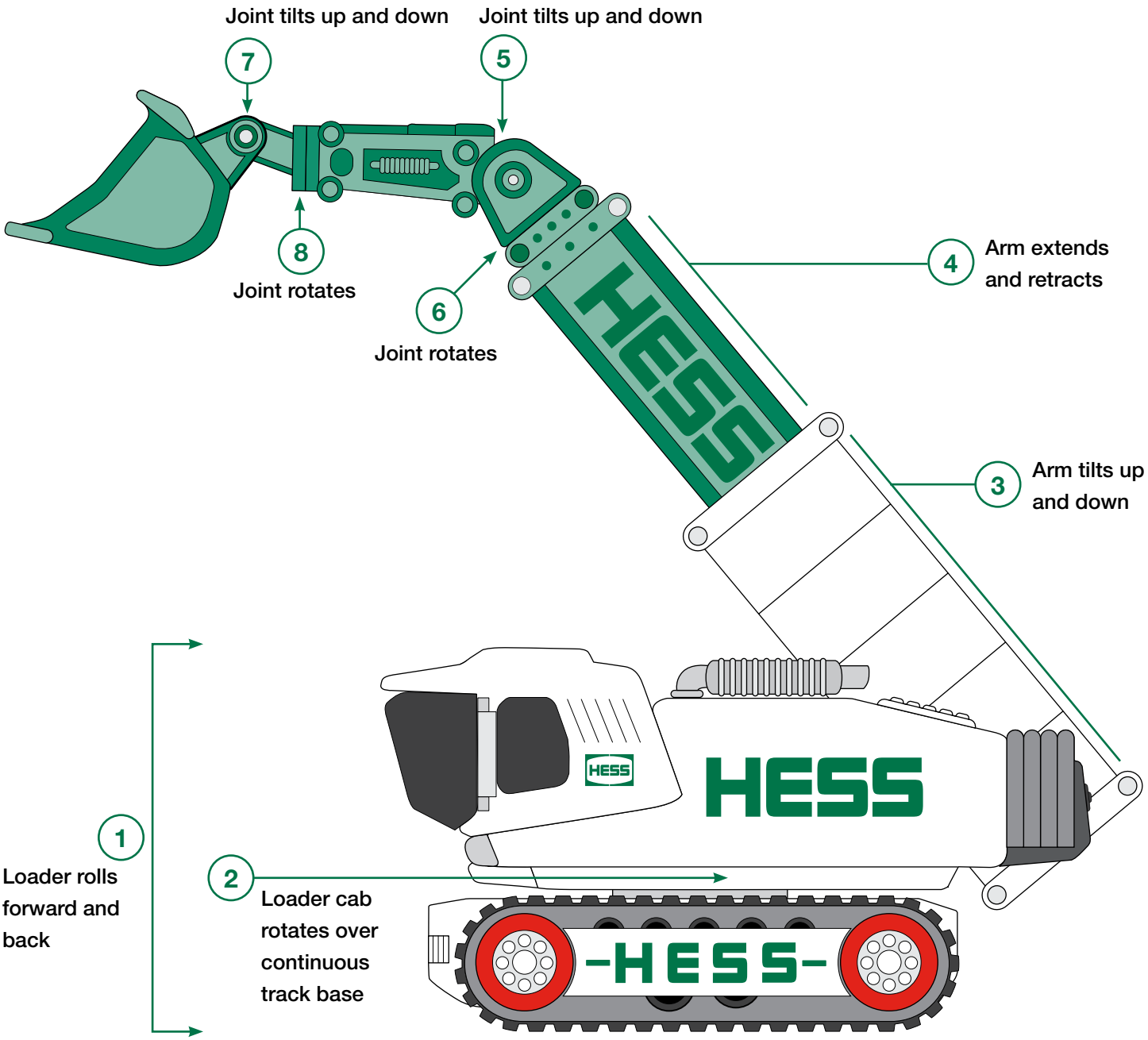
9 _____

10 _____

11 _____

12 _____

TEACHER ANSWER KEY



5. LOADER GAMES

Operators of full scale construction equipment, similar to the 2017 Hess Loader, sometimes enter contests to demonstrate their skills in handling their vehicles. Competitions include digging the deepest hole, moving and piling up the most dirt, loading a dump truck, maneuvering through obstacle courses, picking up and moving delicate objects, etc. The competitions are fun but they also demonstrate skills required by the operators in their daily work.

Maneuvering a heavy work vehicle like the Loader requires lots of skill. The operator not only has to drive and position the vehicle in the right location but also operate a multi-jointed arm. Movements of the arm requires exact positioning of each of its many joints to accomplish a task. Training and practice and more practice is essential for workers in this STEM-related construction job.

Today, two new contests have been created: "Load the Loader" and "Loader Bowling."

In the "Load the Loader Contest," operators will aim their Loaders at their truck ramps from a set distance. The Hess Dump Truck is designed to carry its Loader. The retractable ramp (inclined plane) located at the rear of the truck enables the Loader to climb and nestle into the truck bed. Clearance for the Loader is small, so precise driving is required to load it safely and securely. The goal is for the Loaders to travel on their own to the truck ramp, scale the ramp, and successfully berth in the truck bed. Through practice, operators will observe how accurately the Loaders travel a straight line and make any necessary adjustments to ensure the loader reaches the center of the truck loading ramp in direct line with the truck bed.

In "Loader Bowling," operators use their Loaders to try and knock down as many cardboard "pins" as possible.

THE QUESTION

What operator skills are needed to successfully compete in loader games?

MATERIALS

Per team of 2–4 students

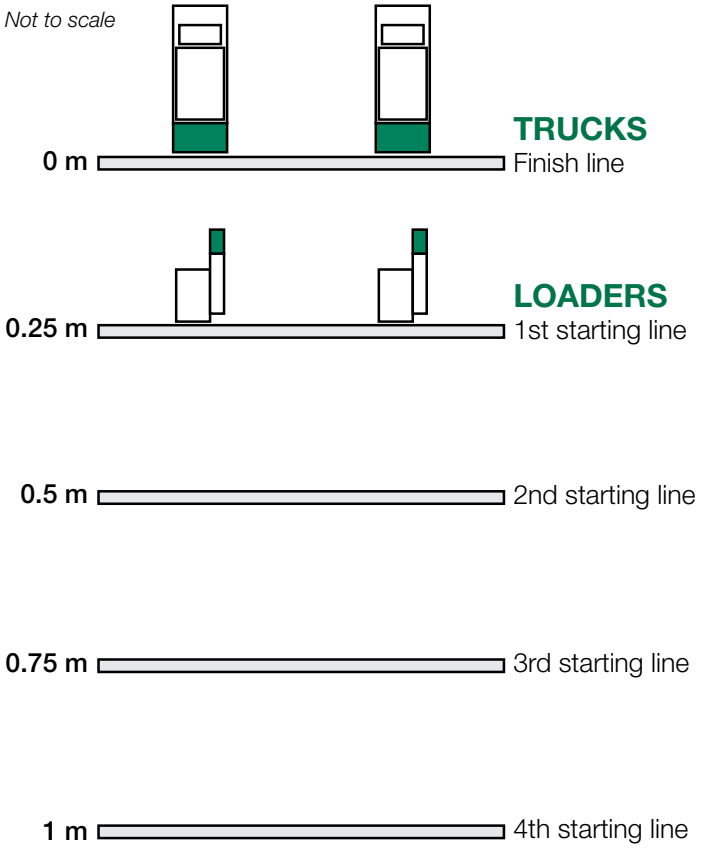
- 2017 Hess Dump Truck and Loader
- 20 center tubes from paper towel rolls (ask students to bring them in from home)
- Awards for the winning teams (snack bars, certificates, extra credit, etc.)
- Masking tape
- Meter stick
- Various materials that teams identify to help them succeed (see "Management Tips")

MANAGEMENT TIPS

Before individual 2017 Hess Loaders are packaged with Hess Dump Trucks, they are tested for their ability to move in a straight line. Student teams will rely on this quality control property during two competitions.

Prior to class, prepare an open area on a tile floor for the first competition, "Load the Loader." Make as many competition fields as needed for your class. Create a competition field by stretching lines of masking tape across the floor, long enough for two teams to set up their dump trucks side-by-side at the 0-meter line (finish line). Stretch parallel tape lines at 0.25 meter, 0.5 meter, 0.75 meter, and 1.0 meter (see illustration, page 23).

Continued



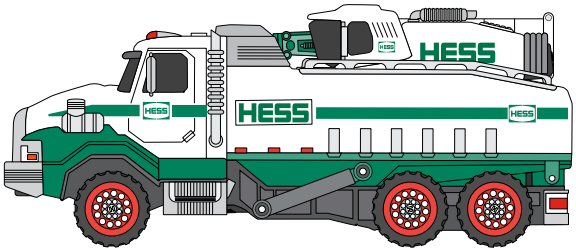
Encourage students to think of unique, effective ways to aim the Loader accurately. For example, teams might draw a chalk line to the truck. Alternatively, they might use materials (paper, paper towel roll tubes, sticks, etc.), to create a sighting device. Encourage "out of the box" thinking.

Upon completion of the first contest, prepare the "bowling alley" for the second game (see illustration, page 24). Teams, two at a time will take turns trying to make a strike or at least a spare by running their loaders from behind the fowl line to the pins. The team that knocks down the most pins in two tries wins the round. Have winning teams compete until all but one team is eliminated.

For "Loader Bowling," two side-by-side bowling lanes will have 10 paper towel tubes, each arranged like bowling alley pins. The triangular shape of the pin area should be three times as wide as the loader and 2 meters from the "foul line" (starting line; see illustration, page 24). Put small tape marks on the floor so that pins are set up exactly the same way for each test.

PROCEDURE

1. **Load the Loader.** Begin the "Load the Loader" contest. Have all teams place their trucks on the 0-meter line on their competition fields. Have them set and align their loaders just in front of the 0.25-meter line.



2. Explain the contest rules for the first competition to the class. The objective is for each team's loader to cross a distance of 1 meter, climb up the truck's loading ramp, and load itself into the truck bed. Once the loaders are on their way to the trucks teams may not touch them until the loaders successfully load themselves on the truck or collide with the truck. If the loader collides with the truck, the team has to try again. The contest will begin at the 0.25-meter line. When a team has successfully loaded the loader from this distance, they move their loader back to the 0.5-meter line and try again. When they achieve success, they will move to the 0.75-meter line. The first team that successfully loads their loader from the 1-meter line is the winner.

3. Give teams time to practice their skills. One team member will be the "operator," who aims and turns on the forward switch. Another team member can assist in sighting/aiming, and a third can retrieve the loader for subsequent practice runs. If desired, the contest can take place the next day.

4. Briefly review the competition rules.
   - Place your truck with the ramp extended down just past the far side of the 0-meter line.
   - Place your loader just in front of the 0.25-meter line.
   - When the contest starts, send your loader on its way. You may not touch the loader again until it either loads itself on the truck or crashes.

Continued

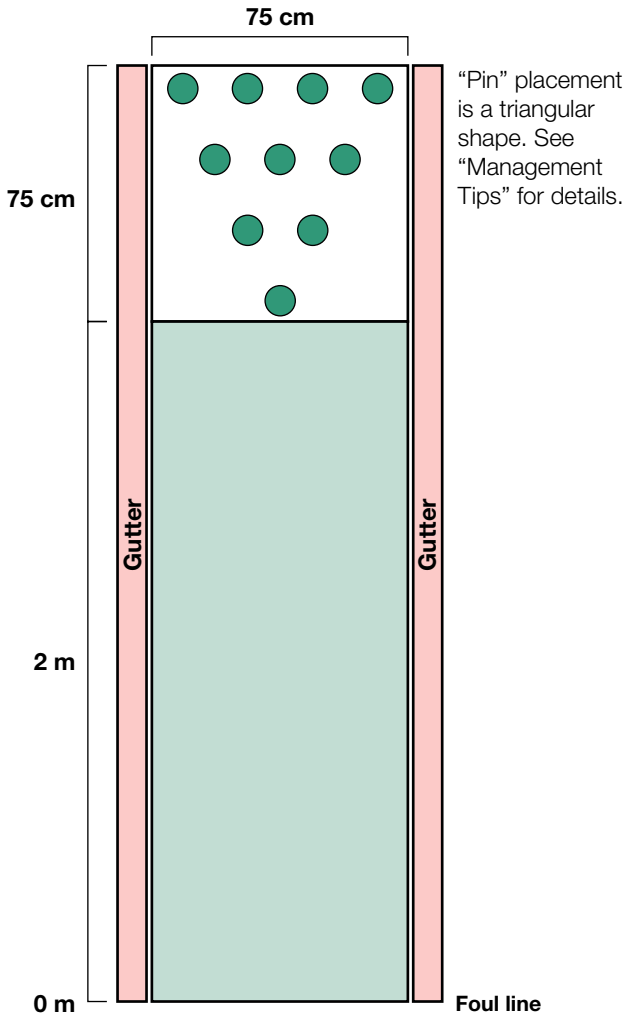
- The team member positioned at the truck may hold the truck in place if the loader pushes it away.
- You may not interfere with the loader from the other team.
- When you are successful in loading your loader from the 0.25-line, move it to the 0.5-meter line.
- The first team that achieves success from the 1-meter line is the winner.

5. Do a countdown to start the competition.

6. After the winning team is determined, have all teams discus what they learned from the competition. What did they have to do to be successful? What problems did they encounter? For example, if the Loader did not travel on a straight path, what caused this? (More friction with the floor on one track than the other, the continuous rubber track slipping slightly on one side or the other, etc.) What did teams do to correct for problems?

7. **Loader Bowling.** Prior to the competition, setup the testing area on the floor. Create two side-by-side bowling alleys. The distance between the foul line and the first pin should be 2 meters (see illustration, right). Put tape on the floor to mark the location for each of the 10 paper towel tube pins.

8. Briefly review the competition rules.
   - Two teams will compete at the same time.
   - Place your Loader with its front just behind the 0-meter line (foul line). Loaders can be placed anywhere behind the foul line but not beyond the side lines ("gutters").
   - The object is to knock down all 10 pins in one or two tries. Knocking down all 10 pins in the first try is a strike and if all are knocked down in two tries it is a spare.
   - If only one team knocks down all 10 pins, it is the winner. If two or more teams knock down all 10 pins, one or more additional rounds will be held by those teams until all but one team is eliminated. If no team knocks down all 10 pins, the team that knocks down the most is the winner.



Not to scale

Tip: Do not remind teams that the chassis of the Loader can be rotated 90 degrees and the arm extended to make the Loader wider so that it knocks down more pins at a time. Let teams figure out this one themselves.

WRAP IT UP

Have teams discuss their strategies for the two competitions. Ask students, *What worked? What didn't. Did you have problems with the Loader's center of gravity? What problems did you encounter and how did you solve them?*

EXTENSION

Locate and show backhoe competition videos from the Internet (a machine similar in purpose to the 2017 Hess Loader). Search "backhoe competitions."

6. BRIDGES: SUPPORTING HEAVY LOADS

According to the U.S. Department of Transportation, Bureau of Transportation Statistics, there were approximately 600,000 bridges in the United States in 2006. Bridges come in all sizes and have many purposes: multi-lane highway bridges; city bridges across rivers; rural one- and two-lane bridges that see little traffic. Some bridges are short, while others span wide waterways or canyons.

One characteristic of a properly designed and constructed bridge is the ability to safely support the very heavy loads. A real truck like the 2017 Hess Dump Truck is a heavy load and when carrying the loader or other materials, it can be a very heavy load. A successful, safe bridge would have to be able to support the truck and its load without cracking or noticeably sagging.

Bridge design engineers have challenging and exciting jobs. They must understand the capabilities of building materials, the science and engineering of bridge design, and outside factors that could affect the bridge's long-term stability (e.g., potential high speed winds, earthquakes, extreme heat, frequent flooding, etc.). Most bridges consist of a very heavy steel frame and a road surface of heavy concrete. Thus, designers must ensure that a bridge will be strong enough to support not only the vehicles crossing it at one time, but also its own weight. Another concern is the ground upon which the bridge's supports rest. How strong is the rock or soil that supports the structure?

This activity presents a big challenge. Each student team will act as a "company" that has been contracted to design and build a temporary bridge that permits the 2017 Hess Dump Truck and Loader (stacked) to cross a deep ravine safely. City developers are building an industrial park, and they need trucks to enter the area with loaders and various construction supplies. Seeking to minimize the project's impact on the environment, they are not willing to cut down the beautiful forest surrounding the site on three sides. The only acceptable way to access the site is to build a temporary bridge across the ravine. It will be replaced with a permanent bridge when industrial park is ready for occupants.

THE QUESTION

Can your team construct a bridge strong enough to permit the 2017 Hess Dump Truck and Loader to cross safely?

MATERIALS

Per class*

- Low-profile electronic scale or flat kitchen scale
- Several books (to serve as the banks of a ravine)
- Meter stick or metric tape measure

* See "Management Tips" for optional/additional supplies

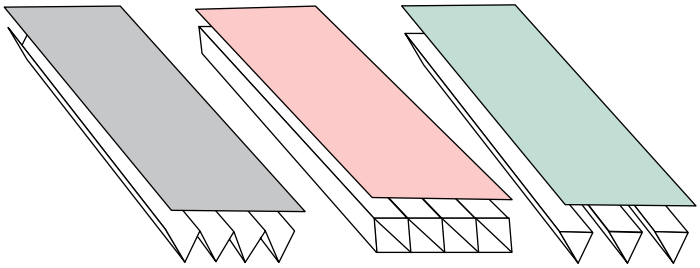
Per team of 2–4 students

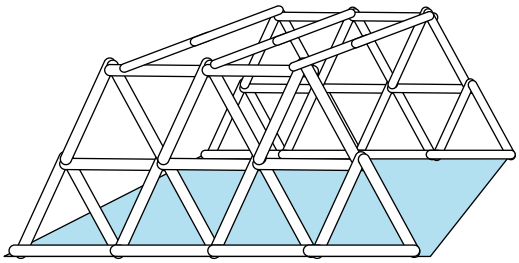
- 2017 Hess Dump Truck and Loader
- 2 file folders
- 2 meters of masking tape
- Ballpoint pen
- Ruler
- Scissors
- Copy of "Bridging the Gap" page

MANAGEMENT TIPS

Stretch out two, 1-meter-long strips of tape for each team,

and lightly press the strips to each team's table surface. Students will tear off pieces as needed. This will prevent teams from using excessive amounts of tape for their bridges. Collect and display photos/pictures of rural bridges from the Internet to provide ideas for student teams. Do not raise bridge supports more than 25 cm. If a bridge collapses, the truck will have only a short distance to fall and should not be damaged. As extra protection, you can place some cushioning beneath the bridge. Procedure Part One: Load Testing can be run concurrently with Part Two: Bridge Construction and Testing.





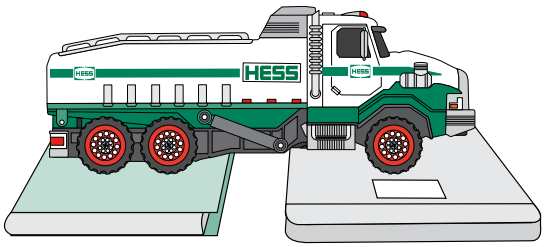
A successful bridge can be made from just two file folders and masking tape. If desired, additional supplies can be made available for construction such as craft sticks, drinking straws, toothpicks, and white glue.

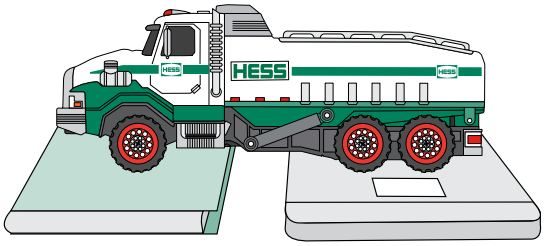
Bridge testing can take place the next day when all teams have completed their bridges. Start with the Truck only. If the bridge holds, add the Loader. (See "Extension" for additional tests that can be performed.)

PROCEDURE

Part 1. Load Testing

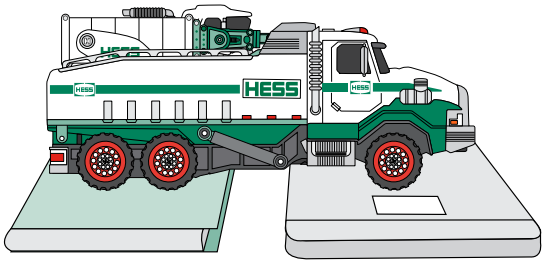
1. Prepare a load testing area for student teams. Place a low-profile or flat electronic kitchen scale on a clear surface. Place a book of equal thickness to the scale alongside the scale, separated by 10 cm (4 in.).

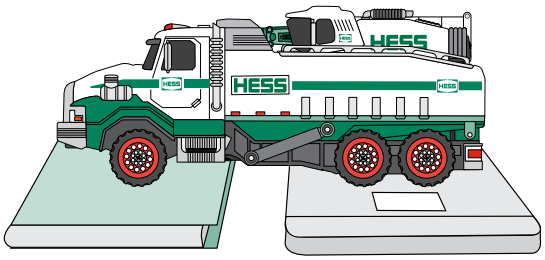




2. One at a time, direct teams to bring their trucks and loaders to the load testing area. Have groups measure the weight of the truck. Have students place their trucks' front wheels on the scale and rear wheels on the book. Instruct teams to measure and record the weight on their student sheets, then reverse the truck as shown above, and weigh and record again.

3. Have students repeat Step 2 with the Loader placed inside of the truck's bed. Students should record their results on the student sheet.





Part 2. Bridge Design, Construction and Testing

1. Introduce the challenge to the class. Using materials provided, each team must construct a bridge that spans a gap of 35 cm (14 in.) and is able to support the 2017 Hess Dump Truck with the Loader in the truck bed.

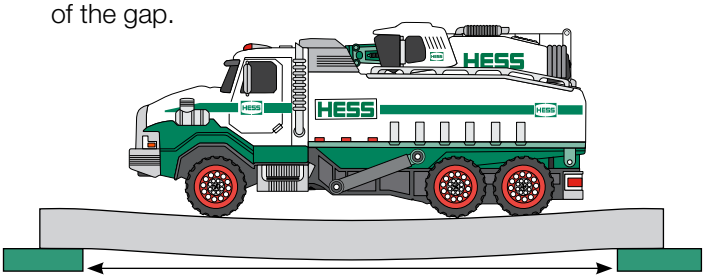
Continued

2. Show teams pictures of rural bridges collected from the Internet. Discuss the different bridge shapes and materials used to construct the bridge provide strength to support crossing vehicles.

3. Discuss the materials that teams will use for their bridges, explaining that each team will be restricted to two meters of masking tape and two file folders. Therefore, it will be essential for teams to plan their bridge designs in advance. Have students sketch ideas for the bridge on their student pages.

4. File folders can be cut and folded in many different ways (see illustrations, page 26). Show teams how to make neat, accurate folds in the file folders. Use a ruler to measure the position of the fold. Draw a line with a ballpoint pen where the fold will be. Pressing hard on the line to score the paper will make it easy to fold the heavy paper.

5. Have teams discuss different ideas for their bridge, vote on which idea to use, and then begin construction. Remind teams that their bridges must be longer than the 35-cm span to be securely supported on both sides of the gap.



6. When a team completes their bridge, have them place its bridge across the ravine gap. Then have the team place its truck, with the loader in the bed, on the center of their bridge. Ask students, *Does the bridge support the truck and its loader? Does the bridge sag? Does it collapse? Is the bridge safe for truck traffic?*

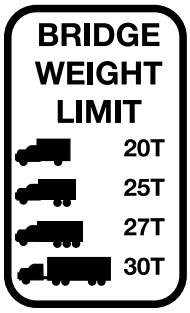
7. If team's bridge fails to support the truck with its load, have the team discuss what went wrong and come up with a solution to make the bridge work. Provide additional materials as needed to repair and strengthen the bridge or to rebuild the bridge. Then have the team test it again.

WRAP IT UP

Discuss what teams learned about building a successful bridge. Ask students, *What worked, and what didn't?* Have each team describe its' bridge design. Ask, *How did you decide on a design? Did the bridge hold? Did it bend or buckle?*

Continue by asking, *What did you learn about the load of your trucks with and without the loader in the bed? Why do dump trucks and other large trucks have more wheels in the back than in the front?* Without the loader, the two ends of the truck exert nearly the same force on the scale. With the loader, the truck is much heavier in the rear than in the front. A bridge design must account for such differences in the distribution of the weight over a truck's wheels. Truck length is another factor. Longer trucks spread their weight farther across a bridge surface and stress the bridge less than do shorter trucks of the same weight.

Ask students, *Have you seen bridge weight limit signs? Can you explain why these signs show different weight limits for different-sized trucks?*



EXTENSION

Conduct a competition to determine which team's bridge supports the most weight. This is called destructive testing. Ask students, *How much weight can each bridge support before collapsing?* Place a sealed water bottle or book on each bridge. Continue adding more until each bridge collapses.

BRIDGING THE GAP

_____
Name

LOAD TESTING

Record your load testing results below.

Weight without Loader in the Truck

Front of Truck:_____ Rear of Truck:_____

Weight with Loader in the Truck

Front of Truck:_____ Rear of Truck:_____

Explain why the truck has four wheels in the back instead of two. Use your test results in your explanation.

_____

_____

_____

BRIDGE DESIGN AND CONSTRUCTION

1. On the graph below, draw possible designs for a bridge to support your team's Dump Truck and Loader. Number each design. Use the back of this sheet if you need more room.
2. Compare your designs with those of your team members. As a team, decide which design to use.
3. Construct your team's bridge.

7. WRITING FOR STEM

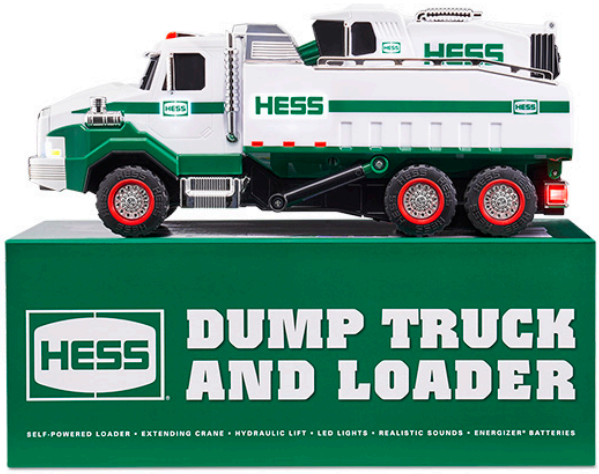
STEM, or science, technology, engineering and mathematics, is a broad education and career category encompassing many disciplines and a wide range of related careers, including some that do not require a four-year college degree. For example, there are two-year programs that prepare candidates for jobs such as dental hygienist, graphic designer, air traffic controller, registered nurse, and electrical technician. Below is a small sampling of STEM careers from the U.S. Bureau of Labor Statistics.

- Aerospace Engineer
- Agricultural Scientist
- Architectural and Engineering Manager
- Atmospheric Scientist
- Biochemist
- Biomedical Engineer
- Computer and Information Scientist
- Computer Systems Analyst
- Environmental Engineer
- Epidemiologist
- Life Scientist
- Mathematical Technician
- Mechanical Drafters
- Mechanical Engineer
- Petroleum Engineer
- Physician
- Science and Mathematics Teacher
- Software Developer
- Teacher
- Website Developer

For a more complete and diverse list of STEM occupations, visit the Bureau of Labor Statistics website at https://www.bls.gov/careeroutlook/2014/spring/art01.pdf.

One STEM career often overlooked is that of technical writer. Technical writers write the manuals or instructions for devices, machinery, and processes. They prepare documents and manuals to communicate complex and technical information and operating instructions. They also help companies and government agencies communicate important information to their workers and the general public. Technical writers also may write magazine articles and content to websites.

To be a good technical writer, it is helpful to be well-versed in STEM fields. Technical writers must be able to communicate with scientists, technicians, engineers and mathematicians,



and then translate these professionals' work into terms that others can understand. In the process, technical writers are able to witness groundbreaking research, see new inventions, and watch exciting discoveries in the making.

In this activity, student teams will practice technical writing by creating an instruction manual for the 2017 Hess Dump Truck and Loader.

THE QUESTION

What do users need to know to operate and maintain the 2017 Hess Dump Truck and Loader in good condition?

MATERIALS

Per class

- Computers and printer access (optional)

Per team of 2–4 students

- 2017 Hess Dump Truck and Loader with the box and instructions
- Glue stick or clear tape
- Scissors

Per student

- Copy of the student page, "Technical Writing"

MANAGEMENT TIPS

Do not let students see the box or instruction card that

come with the 2017 Dump Truck and Loader until Step 5 in the instructions.

The packaging box for the Dump Truck and Loader provides a lot of information about the vehicles and their use, and includes an instruction card that explains how to replace the cells in the battery compartments. In this activity, student teams will produce operating instructions for either the Dump Truck or the Loader. The Dump Truck has fewer mechanical parts than the Loader, but many more buttons. It will be more challenging to write instructions for the Loader, so you may wish to consider individual abilities when making team assignments.

For information on the vehicles, maintenance tips and more, see "The 2017 Hess Dump Truck and Loader," on page vii.

PROCEDURE

1. Begin a discussion with your students about STEM careers by asking if they have ever bought or received something that came with assembly or operating instructions (bicycle, smart phone, board game, etc.). Ask students, *How easy were the instructions to follow? Where did the instruction come from? Have you heard the job title,* Technical Writer, *and do you know what a technical writer does?* Explain that technical writers must have a good understanding of STEM fields so that they can write manuals and instructions for operating exciting new inventions and explain the procedures for complex projects, such as launching missions to outer space. Tell students they will gain experience with technical writing by creating instructions for use and maintenance of the 2017 Hess Dump Truck and Loader.

2. Group students into the same teams with which they have been working, and have each team write a user's manual for the Dump Truck or Loader.

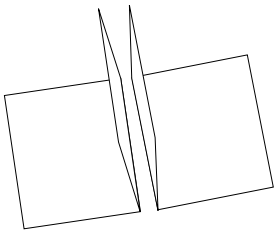
3. Have teams make a list of everything a user should know about the vehicle they chose—how it works, what the buttons or switches do, how it moves and so on. Have teams divide up the manual into parts and assign each of the parts to different team members to write.

   Typically, instructions will include one or two introductory sentences explaining what is going to be described, followed by a numbered list outlining the steps to be followed.

   Example: "How to Change the Cells in the Loader Battery Compartment."

   1. Use a small screwdriver to unscrew the black battery cover.
   2. Remove the cover.
   3. Remove the cells.
   4. Put in new cells, being sure to insert them in the same direction as the old cells.
   5. Replace the cover.
   6. Screw the cover in place.

4. When each member of a team has completed his or her assignment, have the team compile and organize the written sections into a complete instruction manual. If desired, have teams cut out each page of their manuals along the solid lines bordering the writing spaces on the student page. Then have them fold the pages on the dashed lines and join the pages into a book with a glue stick or clear tape.



Glue or tape folded sheets together to make a book.

5. Permit teams to compare the Truck and Loader box and instruction card with the manual they produced. Did they miss anything that should have been described? Are their instructions as clear as the instructions provided with the Truck and Loader? Are their instructions better? Is there anything missing that should be on the box or the provided instruction card? Have teams share their thoughts with the class.

WRAP IT UP

Have teams share their manuals with the class. Discuss each manual, asking the class if the manual is complete, or if additional steps/directions should be included.

Continued

EXTENSIONS

- Share some actual technical manuals from other products with your students. Examples to show include the manual for a computer, automobile, personal care products like a hair dryer, computer game, power tool, and TV remote controller. Ask students, *Do the manuals include safety information? How is the safety information presented to catch the user's attention? Why do many manuals include information in other languages?*
- Relate technical writing to other forms of instruction such as recipes and travel directions.
- Have students practice writing technical manuals for basic activities such as instructions for making a peanut butter and jelly sandwich. Other possibilities include how to brush and floss your teeth, how to play a game like Tic-Tac-Toe, etc.

TECHNICAL WRITING

Name

INSTRUCTIONS

As a team, select either the Hess Dump Truck or Loader and use the space below to describe it or a part of the vehicle you have been assigned to detail. Feel free to add pictures to help in your explanations.

Product Name and Part	**Steps** (Numbered list providing details a user should to operate and maintain the vehicle or part)
Title	
Introduction (One or two sentences explaining what is going to be described)	
Description (Include tips, cautions and information not listed in "Steps")	

8. ADDING AN "A" TO STEM

The STEM disciplines can prepare students for rewarding careers in a number of fields. Other disciplines beyond traditional STEM fields also can be integrated into an effective STEM education. Examples include social sciences, health, reading, writing and the arts.

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The work done in STEM disciplines leads to many of the products we depend upon every day. However, it is not enough just to create a product, like a smart phone or a new vehicle. To be successful, the product also must look good and fit the user, both physically and emotionally. That is where arts come in. Art design and innovation fit into STEM and turns it the acronym to STEAM.

The old phrase, "Build a better mousetrap and the world will beat a path to your door," doesn't quite reflect modern life. Today, new products and services must be "marketed" to potential customers, making them aware of the products and the benefits they can provide. Successful marketing requires effective communication, which is a true art form. It involves creating a plan to introduce a product and the use of advertising, such as attractive logos and color schemes; enticing promotions for social media, magazines, billboards, and websites; and even television or website commercials.

In 1964, a new toy was introduced to markets in the northeast United States: a toy gasoline delivery truck, sold as a promotional item for the Hess gas station chain. The truck cost $1.29, and included lights and came with a free battery. It became an instant hit. A new truck design has been released every year since. The 2017 Hess Truck—a dump truck with a tracked loader vehicle—represents a new category of vehicle not produced in this line before.

In this activity, student teams will form marketing companies, each challenged to propose a marketing plan (AKA: "pitch") for the 2017 Hess Dump Truck and Loader.

THE QUESTION

What is the best way to market the 2017 Hess Dump Truck and Loader?

MATERIALS

Teacher

- Smart Board or LCD projector and screen

Per class

- Computer and printer access

Per team of 4–5 students

- 2017 Hess Toy Dump Truck and Loader
- Art supplies, including poster boards
- Copy of "Marketing Plan," "Marketing Company Organization," and "Presentation Outline"

MANAGEMENT TIPS

Each team will determine the materials needed for the activity, based on its advertising approach. Encourage teams to bring materials from home and materials that are available in your classroom. Also encourage teams to make use of technology such as Powerpoint or Keynote for their presentations.

Introduce the project and have teams hold their first meeting. Their objective is to assign team roles and produce a draft a marketing plan. Allow teams to meet for 30 minutes to an hour a day over the next several days to refine their plan and create a brief presentation outlining the plan's merits.

Continued

PROCEDURE

1. Divide the class into "advertising companies" of 4 to 5 students each. Introduce the project to your students. and distribute the student sheets. Have teams come up with a company name and assign jobs, such as President, Head Writer, Lead Graphic Designer, Talent (on-camera), and Photographer/Videographer. The titles are mostly a formality, as all team members should participate in every stage of planning and executing the marketing plan.

2. Tell teams they have one week to develop their plans and presentations. Explain that a brief presentation of marketing or other business ideas is called a "pitch." Provide class time (30 minutes to 1 hour each day) for teams to work on their plans, and offer them the opportunity to come in after school or at other times, if needed.

3. Lead a class brainstorming session to identify and list ideas for their marketing plans and pitches.

4. At the end of the week-long development process, hold a formal Pitch Day, during which each team will have five minutes to pitch its plan. Invite an available parent, faculty member or administrator from your school to attend the session and play the role of a Hess Truck marketing executive. That person will decide which team wins the marketing contract.

   Note: It is not necessary to pick only one team as the winner. Marketing executives often ask advertising companies to return later with refined plans. Several or all student teams might be asked to do that. The project can end at this point.

WRAP IT UP

Have the Hess marketing executive talk about the positive elements of each team's pitch.

EXTENSIONS

- If teams wish, allow them to continue working on their marketing plans and pitch them to the class at a later date.
- Display the visual products created by each team in the classroom or outside the room in the hall. These products could make nice displays for open house or parent events.

MARKETING COMPANY ORGANIZATION

INSTRUCTIONS

1. Pick a company name and write it in the space below.

Company Name

2. Assign the following jobs to team members. Write each person's name in the appropriate box below.

President

Coordinates the efforts of all team members. Introduces the team during the pitch to the Hess Marketing Director.

Head Writer

Prepares the text for advertisements, email blasts, news releases, posters, and scripts for commercials.

Lead Graphic Designer

Makes decisions about design, artwork, photos and videos used in print advertisements, social media and TV commercials.

Photographer/Videographer

Operates cameras for TV commercials and social media; composes and shoots still photos for print advertising.

Talent

Appears on camera to demonstrate and talk about the product; poses for advertising photos.

MARKETING PLAN

Company Name

INSTRUCTIONS

Answer the "Four Ps of Marketing" questions below. Use the back of this sheet if you need more room.

1. **P = PRODUCT.** What is a good description of the product? Keep description short and to the point.

2. **P = PRICE.** How much should we charge the customers for this product? What is included in or with the product—or not—such as batteries, gift message, product box, shipping box, shipping charges, etc.)?

3. **P = PROMOTE.** How should the product be promoted or advertised? List different ideas below.

4. **P = PLACE.** Where should the product be sold? Which places will be the most effective in generating sales?

PRESENTATION OUTLINE

Company Name

INSTRUCTIONS

List below the things you will say in your pitch to the Hess marketing executive. Also list the illustrations (pictures and charts) you will exhibit to make your points. Use this outline in making your presentation. Be sure each member of your team has a part in the presentation. You will have 5 minutes to make your pitch.

GLOSSARY

Compound Machine
A collection of two or more simple machines that work together for a common purpose.

Degree of Freedom
The number of movements the joints on a robot arm or the Hess Loader are capable of.

Force
Any interaction which, without interference, changes the motion of an object; has both magnitude and direction.

Friction
Force resisting motion or movement.

Fulcrum
Pivot point for a lever.

Gears
A set of wheels and axles that have teeth to interlock with each other to transmit force and movement when they turn.

Hydraulic Ram
A compound machine that transmits force between cylinders to extend the length of a ram or shaft.

Ideal Mechanical Advantage (IMA)
Theoretical mechanical advantage without the effects of friction.

Inclined Plane
A simple machine with a sloped surface or ramp for moving objects.

Input
The force exerted into a simple or compound machine.

Lever
A simple machine consisting of a beam or poll that rotates about a pivot point to transmit force and motion.

Marketing
Promoting and selling and distributing products or services. May include moving goods from producer to consumer.

Mechanical Advantage (MA)
The measure of force and distance transmitted by simple and compound machines; amount of effort required to complete a job.

Output
The force transmitted by a simple or complex machine.

Pulley
A simple machine consisting of a grooved wheel and axle and a rope, wire, or belt that loops around it to transmit force and motion.

Ram
A pole or shaft that extends to move objects such as tilting up the dump truck bed.

Screw
A simple machine consisting of a shaft with grooves wrapped around it to transmit force and motion when the shaft is rotated.

Simple Machine
Mechanical device that changes the direction or magnitude of a force; in general, six simple machines as defined by Renaissance scientists; in combination may be used to make compound machines.

Slope
A surface where one end or side is at a higher level than another; a rising or falling surface.

STEM
Acronym for Science, Technology, Engineering and Mathematics

Wedge
A simple machine, consisting of two back to back inclined planes, that is used for cutting or spreading apart materials.

Wheel and Axle
A simple machine consisting of a circular disk and a shaft about which the disk rotates.