Ignite Learning

A STEAM Exploration with the Hess Fire Truck

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Baylor College of Medicine

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BioEd℠

Teacher resources from the Center for Educational Outreach at Baylor College of Medicine.

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Contents

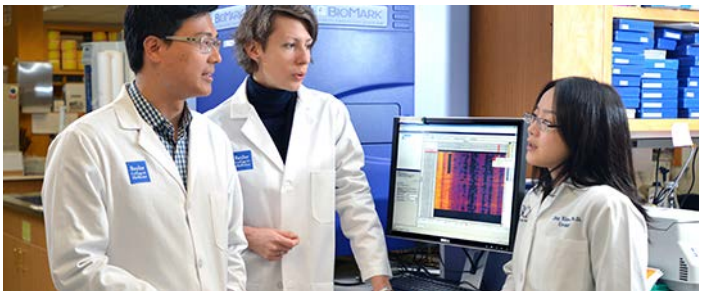
ORDER OF ACTIVITIES AND HESS TOY AVAILABILITY

- The order of the activities may be changed if it will create a more logical progression for the classroom.
- The 2024 Hess Fire Truck with Car and Motorcycle is available at www.hesstoytruck.com while supplies last.
- Activity guides for Hess trucks for years 2016 – 2024 are available on the Baylor College of Medicine Bioedonline.org website.

Baylor College of Medicine

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

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



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

Baylor is ranked by the National Institutes of Health at #1 in Texas and #20 in the nation among all medical schools based on NIH funding. Five departments rank in the top 10, including a ranking of #1 in genetics. Baylor College of Medicine is ranked in Tier One for research-intensive schools by *U.S. News & World Report*, along with 15 other medical schools.

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The Center for Educational Outreach at Baylor College of Medicine provides a wide range of educational programs and resources that help prepare and encourage students to pursue careers in medicine and the health sciences. Offerings include teacher professional development and curricular materials that improve the STEM content knowledge and skills of K–12 students. Educators can 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.

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

Hess Corporation

Hess Corporation is a leading global independent energy company engaged in the exploration and production of crude oil and natural gas. At Hess, social responsibility (SR) means maintaining the highest standards of corporate citizenship as we work to deliver the energy the world needs—energy that is fundamental to advancing economic progress and improving living standards.

SR, which is one of the six Hess Values, is foundational to the culture of our company and to our engagement with the communities where we operate; it includes protecting the health and safety of our workforce, safeguarding the environment, and creating a long-lasting positive impact on our communities.

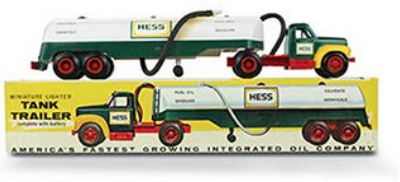
In 2023, Hess invested approximately $41 million in social programs with a primary focus on education, healthcare, and the environment. Above all, we continue to be a company that cares about its people, its impact on the community, its reputation, and doing the right thing.

We are proud of our achievements, which include achieving leadership status in CDP's annual Global Climate Analysis for the 15th consecutive year and once again receiving an AAA rating in the MSCI ESG rating assessment. The company also earned a place on the Dow Jones Sustainability Index for North America for the 14th consecutive year and for the second time was included in the Dow Jones Sustainability World Index. Hess was highly ranked on the Human Rights Campaign's (HRC) Corporate Equality Index for 2023–2024 for LGBTQ+ workplace inclusion and for the fourth consecutive year earned a place on the 2023 Bloomberg Gender-Equality Index (GEI). Other accolades include being recognized as one of America's Most Responsible Companies by Newsweek magazine; ranked a Top 50 Employer by *STEM Workforce Diversity* magazine (15 consecutive years), *Equal Opportunity* magazine (5 consecutive years), *Minority Engineer* magazine (6 consecutive years), *Woman Engineer* magazine (11 consecutive years), and *CAREERS & the disABLED* magazine (13 consecutive years).

Hess has also been recognized as one of America's Most Responsible Companies by *Newsweek* magazine; was ranked a Top 50 Employer by *STEM Workforce Diversity* magazine (14 consecutive years), *Equal Opportunity* magazine (4 consecutive years), *Minority Engineer* magazine (5 consecutive years),*Woman Engineer* magazine (10 consecutive years), and *CAREERS & the disABLED* magazine (12 consecutive years); and was named a Best of the Best Employer by *Professional Woman's Magazine*, *Black EOE Journal* (7 consecutive years), and *Hispanic Network Magazine* (7 consecutive years).

The Hess Toy Truck Story

The Hess company was founded in 1933 when Leon Hess bought a secondhand 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 more than 1,300 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. The Hess Toy Truck remains a beloved holiday tradition and among the best-selling toys in the country every year, now offered exclusively at www.hesstoytruck.com and at HessToyTruck.com/Stem.



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How It's Made

It takes a long time (and a lot of STEM) to create a Hess Toy Truck. The process of developing each new toy starts two to three years before the truck goes on sale. Some trucks have taken as long as six years from concept to market. Initial 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. A Hess Toy Truck generally comprises up to 300 small, hard plastic pieces. 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

Hess Toy Trucks are much more than toys for children or collector's items for adults. They are useful tools that offer a variety of practical and fun ways to teach STEM subjects, such as force and motion and simple and complex machines. STEM is the acronym for science, technology, engineering, and mathematics. It denotes an integrated approach for developing many products and processes we depend on each day. It is also one of the fastest-growing categories for jobs.

Activities in this guide use the 2024 Hess Fire Truck with Car and Motorcycle to explore the concepts of force and motion, basic fire science, geometry, and design. The eight activities contained here are suitable for students in grades 3–8, with modifications for younger children. The order of the activities can be changed as desired. All activities support the Three Dimensions of Science Learning in the Next Generation Science Standards and state science and math standards. Some activities include data and activity pages that can be used for assessment or placed in science notebooks.

The 2024 Hess Fire Truck with Car and Motorcycle represents a versatile group of advanced firefighting equipment suitable for use by urban and rural fire departments to protect homes, businesses, schools, and civic buildings from the ravages of fire. The fire truck is based on a full-scale quint fire truck. Quints are a combination of five complementary firefighting tools: an extendable aerial ladder, water tank, hoses, pumps, and ground ladders. In addition, the Hess Fire Truck has compartments to hold the fire chief car and motorcycle. The truck has a wide range of lights, including adjustable spotlights on the roof for nighttime fire operations. The aerial ladder mounted on the roof extends upward and rotates 360 degrees. The truck also features four buttons that trigger different sirens and motor noises. The truck's rear has a door with a deployable ramp for the fire chief car and two side-doors ramps for the motorcycle.

The fire chief car has its own lights and a pull-back motor that is charged with potential energy when rolled backward and converted to kinetic energy when released. The car's wheels grip the surface they sit on, propelling the car forward at high speed.

The motorcycle has a flywheel system for propulsion. A rapid forward push across the floor causes the flywheel to spin quickly. A gear system transmits energy in the flywheel to rotate the motorcycle wheels. The motorcycle also has a spoiler above its rear wheel that helps the motorcycle perform wheelies.

Fire trucks and their associated equipment reflect all four components of the STEM acronym: science, technology, engineering, and mathematics. Firefighting involves understanding the science of fire and how fires can be extinguished. Fire trucks and the tools they carry are wonderful examples of how firefighting technology has evolved over many hundreds of years and continues to evolve. Constructing firefighting tools involves engineering design that enables firefighters to do their jobs safely and effectively. Mathematics is used in the three other STEM disciplines to measure fire conditions and calculate equipment performance.

Skilled workers in STEM fields are always in demand, with job openings exceeding the number of prepared candidates. This guide provides powerful, stimulating STEM learning experiences that relate to many STEM fields, such as the example careers listed below. These careers require competency in science, technology, engineering, and mathematics.

EXAMPLE STEM CAREERS

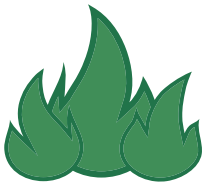
- Automotive Technologist
- Automation Technologist
- Biologist
- Chemist
- Civil Engineer
- Dispatcher
- Electrical Engineer
- Emergency Medical Technologist
- Firefighter
- Fluidics Scientist
- Geoscientist
- Integrity Engineer
- Manufacturing Engineer
- Mechanical Engineer
- Petroleum Engineer
- Safety Engineer
- Structural Engineer
- Software Developer
- Structural Engineer
- Urban Planner

01

Suggested Grades

3-8

Fire, Fire!



What is fire, and how are fires put out?

Suggested Grades **3–8**

1 Fire, Fire!

The Question

What is fire, and how are fires put out?

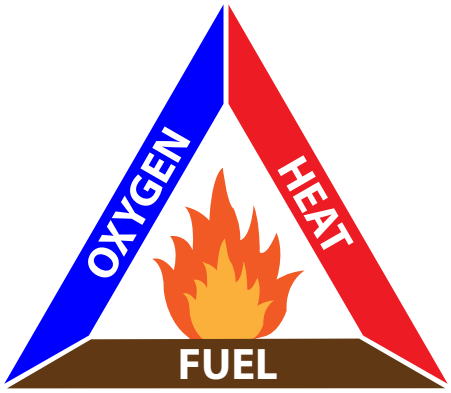
Where's the STEM?

Being a firefighter means much more than having a fire truck and knowing which way to point a fire hose. All firefighters must have solid knowledge of the science of fire and the technology needed to control and extinguish fires.

Fire is more than flames and smoke. It is a complex chemical reaction called *combustion*, which occurs when a fuel (e.g., wood, paper, gasoline) reacts with oxygen. This process is called *oxidation*, which produces heat and light. As molecules rearrange, heat is either released or absorbed. The amount of heat produced depends on how fast this molecular change occurs.

Oxidation can occur slowly or very quickly. For instance, iron easily rusts, or oxidizes, when the atoms in iron combine with oxygen to make iron oxide, but this chemical change is slow and produces little heat. Burning wood, however, is a good example of a fast oxidation process. A match, focused sunlight, friction, or something already burning can quickly trigger a chemical change in wood. When the wood's temperature reaches about 300° Fahrenheit (~148° Celsius), cellulose (a carbohydrate found in the cell wall of plants) begins to decompose and turn into a gas. The gas, composed of hydrogen and carbon compounds, reacts with oxygen in the atmosphere and raises the wood's temperature to about 500° Fahrenheit (~260° Celsius). This reaction breaks down the compounds, producing flames that primarily consist of carbon dioxide, water vapor, oxygen, and nitrogen.

So, what is fire? It is a rapid oxidation process that releases light, heat, and various reaction products. Three things are needed for fire: heat, fuel, and oxygen. These three things are often referred to as the fire triangle. Fire only occurs when all three are present. If one of the three is taken away, the fire goes out. This is the scientific knowledge used in fighting fires. The tools used to extinguish fires are the technology of firefighting.



The following activity consists of several **fire science demonstrations to be done by the teacher** to explain what is needed for fire and some of the ways fires can be put out. The science behind the demonstrations is best suited for older children but can be modified for younger learners. **Note:** Check building regulations regarding fire safety before engaging in these demonstrations.

Management Tips

- See the individual procedures below for the specific materials needed for each demonstation.
- While these demonstrations are generally not hazardous, wearing safety goggles serves as an important reminder to students to protect their eyes during activities that could pose risks. If you bring students close to the demonstration table, they should wear eye protection as well.
- It is recommended that you practice the demonstrations before showing them to your students.

Demonstration 1: Candle Fire

Candles are an excellent tool for the study of fire. In 1848, scientist Michael Faraday gave six lectures on the chemistry and physics of flames at the Royal Institution in London. The lectures are featured in *The Chemical History of a Candle*. The book has been reprinted many times and is readily available online. It is a primary resource for information about the structure and composition of candle flames, as examined in this demonstration. (Other combustible materials may have different compositions and flame color, but the structure of the flame will generally be the same.)

Procedure:

Ask students if they have ever looked closely at the flame of a burning candle. If so, what did they see?

01 Place a candle in a central location in the classroom. Have students gather around but not too close. Darken the room and light the candle.

02 Ask students to share their observations about what they see. *Describe the flame. What is its shape? What do you think causes that shape? What are the flame's colors? What is happening to the candle wax?*

03 If a smart phone camera is available, take several photographs for display on a whiteboard, allowing students to observe the details of the flame's shape and color.

Note: You may have to play with the camera controls, such as exposure settings, to get good images that reveal the flame's shape and colors. If the phone's camera has slow motion capability, capture the flame's flickering motion. Flickering is caused by random movements of air around the flame. Students moving about and breathing create subtle air currents that can affect the flame. Blowing out the flame cools the process below the combustion temperature and spreads out the burning wax vapors. As a result, the temperature drops too low and the vapor becomes too spread out for the candle to remain burning.

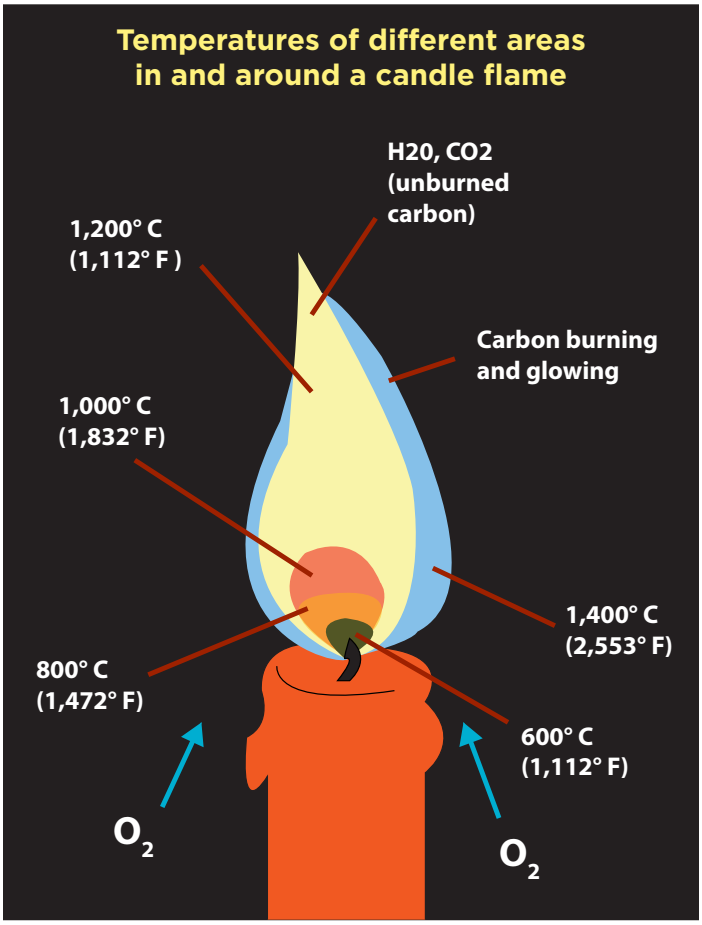
Materials

FOR THE TEACHER

- taper candle or votive candle
- matches
- darkened room
- smart phone camera (optional)

Wrap It Up

- *Why does the candle have a teardrop shape?* When lit, candles produce heat that warms the surrounding air, causing the air to expand and rise. This creates air currents that bring in fresh oxygen to sustain the reaction and carry the glowing gases upward, shaping the flame. As the warm air produced rises, it gradually cools. When it reaches a temperature equal to that of the surrounding air, the rising motions stops.
- *Why are there different colors in the flame?* Flame colors indicate different temperatures: blue represents the hottest areas, yellow indicates the cooler regions, and red signifies the coolest part of the flame.
- *What is happening to the candle wax?* Heat from the burning wick melts the surrounding wax. The liquid wax is drawn up by the wick's fibers (a process known as capillary action). The flame's heat then turns the liquid wax into a gas (or vapor), which reacts with oxygen in the air, releasing light, heat, carbon dioxide, and water vapor. Students might be surprised to learn that the candle wax itself does not burn to create the flame.
- The American Chemical Society offers a detailed explanation of the process in this video: https://www.youtube.com/watch?v=B9asozzeAwY
- *How does knowing flame properties help firefighters put out a fire?* Hot air is less dense (or lighter) than cool air because hot air molecules have more energy, move faster, and spread apart. Firefighters can use this knowledge about how hot air behaves to control a blaze. Because of the hot air's buoyancy, the heat from a fire on the first floor of a building will rise quickly to the floors above and ignite them. Firefighters typically will concentrate on putting out the fire before it can spread upward. This is because the entire structure could be destroyed if a fire reaches the upper floors.
- This effect can be demonstrated by lighting two matches at the same time. It is safer to use long fireplace matches for this demonstration. Hold one match with the head facing up and the other match with the head facing down. Use a candle flame to ignite both matches at the same time. Which one burns faster? The downward-facing match with will burn faster because the flame heats the matchstick above it, causing it to burn more quickly.



Demonstration 2: Fire Out!

Oxygen is one of the three components in the fire triangle. A fire can be extinguished by eliminating oxygen. In small fires, one of the standard ways to do this is by using carbon dioxide, or CO_2. CO_2 does not support combustion. Some fire extinguishers contain compressed CO_2 in a pressure chamber connected to a hose and nozzle. A trigger is pulled, releasing the CO_2 through the nozzle to replace the oxygen that is sustaining the fire. Without the oxygen, the fire goes out. Other methods of extinguishing a fire include covering it with a blanket or lid.

Note: It is important to know that not all fire extinguishers are the same. There are eight different types, each containing various agents tailored for specific fire types. These agents include specialist dry powder, standard dry powder, foam, water spray, water mist, and wet chemical. There is no single fire extinguisher that can be used on all classes of fire.

Materials

FOR THE TEACHER

- fireplace match
- large glass beaker or large glass pickle jar
- white vinegar
- baking soda
- measuring cup with markings for 1 cup (8-ounce) capacity

Procedure:

01 Explain that by combining baking soda (a base) with white vinegar (a mild acid), a rapid chemical reaction occurs that produces the gas carbon dioxide, observed as bubbles.

02 Place about ¼ cup of baking soda in the beaker or jar.

03 With students watching closely, pour in about ¼ to ½ cup of white vinegar on top of the baking soda. Ask students what they observe. They should observe rapid bubbling or effervescence, which indicates the production of CO_2 gas.

04 Light the long-reach fireplace match. Slowly lower the flame into the beaker or jar. What happens? (Flame instantly goes out.)

Wrap It Up

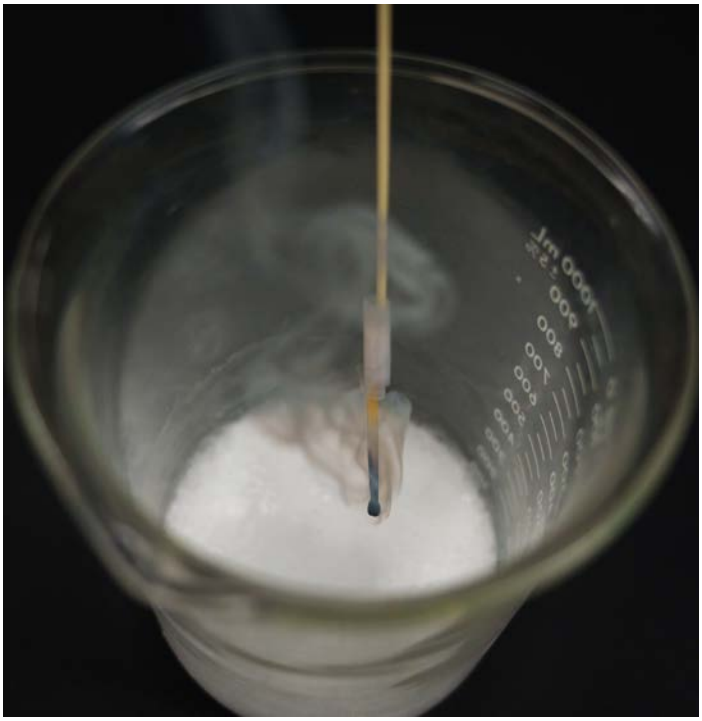
- *Why does the CO_2 produced by the chemical reaction of baking soda and vinegar remain inside the beaker or jar?* Carbon dioxide is approximately 1.6 times heavier than ambient air. The mass difference between the CO_2 and the ambient air causes the CO_2 to fill the jar and remain there while the ambient air, containing oxygen needed for fire, is pushed out.
- *Why does the flame go out?* Carbon dioxide cannot sustain fire. Refer to the fire triangle illustration to remind students that a fire needs oxygen. For older students, explain that the oxygen atoms in the CO_2 molecules are bonded with carbon atoms and not available to oxidize other material to support a fire.
- *How does this help firefighters put out a fire?* Some forms of fire extinguishers hold compressed carbon dioxide gas. These fire extinguishers can be used for quickly putting out small fires, such as a kitchen fire. **However, a CO_2 fire extinguisher is not recommended for kitchen grease fires.** Grease fires are best handled with Class K extinguishers or other methods, such as covering the fire with a metal lid or using baking soda to smother the flame.
- **Advanced topic:** *How is CO_2 produced by baking soda and vinegar?* Baking soda (sodium bicarbonate) and vinegar (acetic acid) react in a two-stage chemical reaction. The first stage produces sodium acetate and carbonic acid:

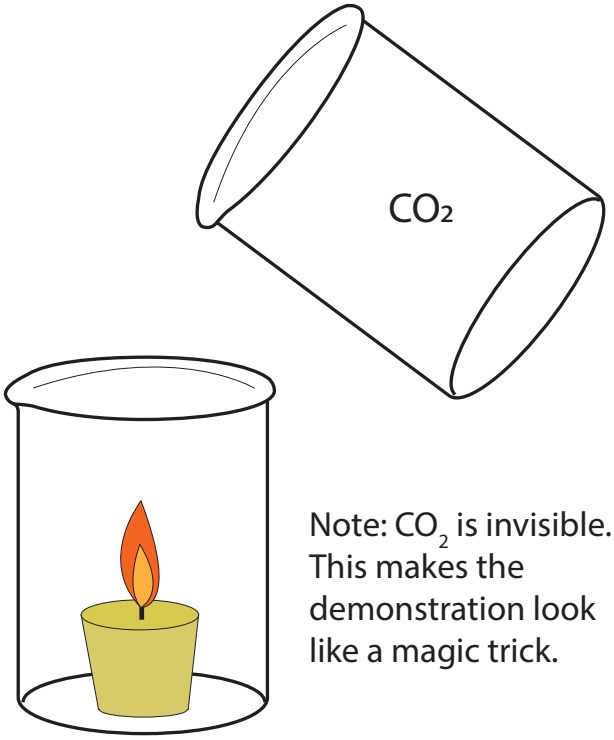
$$NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2CO_3$$

The carbonic acid is unstable and decomposes to produce bubbles of carbon dioxide gas and water that accumulate and replace the air in the beaker or jar:

$$H_2CO_3 \rightarrow H_2O + CO_2$$

- An alternate demonstration requires two beakers or jars and a votive candle. Place the candle inside one glass container and light the candle. You can produce and contain CO_2 gas in the second glass container by holding the mouth of the container above the candle and slowly "pouring" out the CO_2. This looks like a magic trick because the CO_2 is invisible. However, we know it is there because the candle flame goes out.





Demonstration 3: Water Does the Trick

Water is an effective way to put out many fires. Water cools the burning fuel to below its combustion point and the fire goes out. This happens because water has a great capacity to absorb heat. When water hits a super-hot burning fuel, it flashes into steam, which carries away the heat.

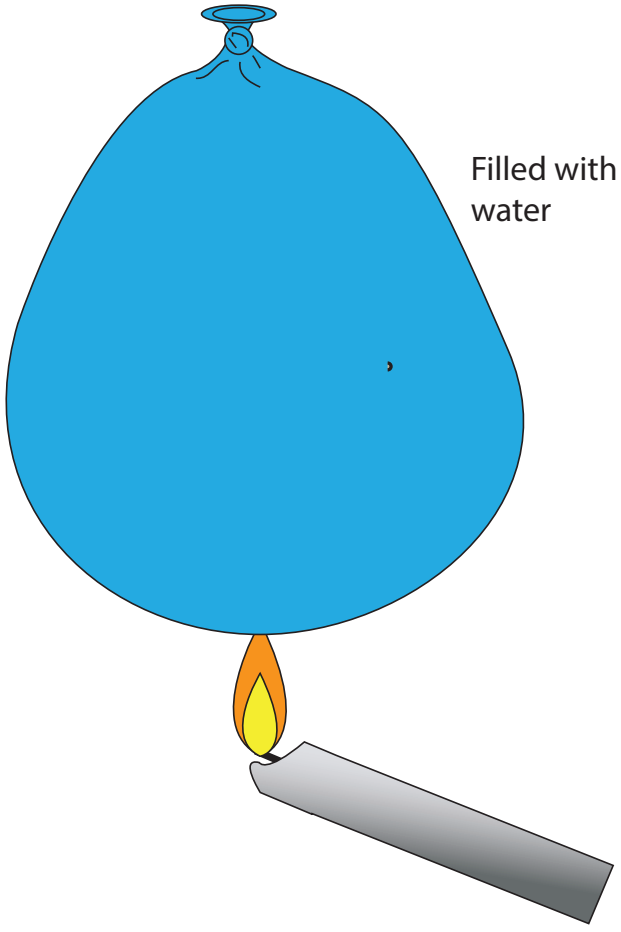
In most communities, water is usually available from fire hydrants. In rural areas, water has to be brought in. An actual tanker truck similar to the Hess fire truck has space for a large water tank that can be filled with water from a nearby river or lake.

Note: A few kinds of fire cannot be extinguished with water. These include electrical fires and fires caused by flammable liquids, such as gasoline, paint, or grease.

Materials

FOR THE TEACHER

- several large round balloons (9-inch balloons work well)
- candle and matches
- water
- clear plastic storage tub



Procedure

01 Fill a balloon with enough water to expand but not overinflate it, then knot the balloon's neck. Inflate another balloon with air.

02 Light the candle.

03 Hold up the air-filled balloon and ask students what will happen if you touch the balloon bottom with the candle flame. They are likely going to say the balloon will pop.

04 Touch the flame to the balloon bottom. It pops!

05 Raise the water-filled balloon over the plastic tub and again ask students what will happen when you touch the balloon with the flame. They will likely think the balloon will pop and make a big mess.

06 Bring the candle to the balloon and touch the flame to the balloon bottom. The balloon doesn't pop.

Wrap It Up

- *Why didn't the water-filled balloon pop?* Water absorbed most of the heat of the candle flame and kept the wall of the balloon from reaching its combustion point.
- *Demonstrations 2 through 4 show us how tackling two sides of the fire triangle (heat and oxygen) can extinguish the flames of a fire. But what about the fuel?* When it comes to burning structures, removing fuel is difficult because the structures themselves are burning. In rural or forested areas, where the fuel is dry grass, shrubs, and trees, removal of fuels is an important firefighting strategy. Forest-fire crews, for example, will try to surround a wildfire with a strip of bare ground called a firebreak. This is done with bulldozers and with hand tools like shovels and even chain saws to cut down rows of trees to make a barrier.

  Sometimes, firefighters will even start a fire to stop a fire. This is called a backfire. A roaring wildfire produces strong, hot air currents that rise into the sky. This reduces the air pressure in the center of the blaze. Winds are created to fill this air pressure imbalance, carrying fresh oxygen to sustain the fire.

  Creating a backfire in the front of a moving fire creates winds that carry backfire toward the main part of the fire, consuming fuel along the way. Then, when the main fire reaches the burned area created by the backfire, it finds little to burn and starts to go out.

Demonstration 4: Money to Burn

Heat is one of the three essential components of the fire triangle. Without sufficient heat, fuel materials cannot ignite and sustain the chemical reaction that creates fire. The word *ignite* simply means "cause to catch fire." Different materials require different amounts of heat to ignite. Here are a few ignition temperatures, listed in degrees Fahrenheit and Celsius.

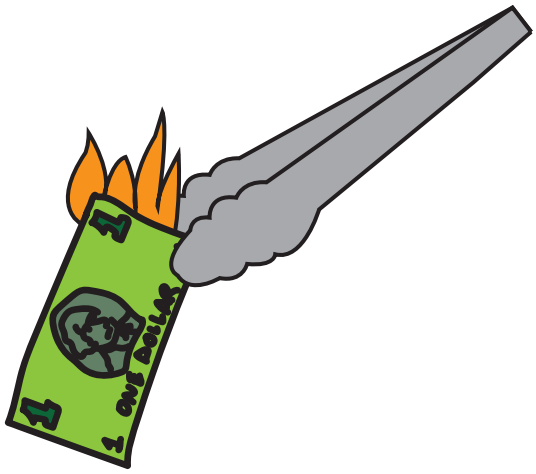
Paper	451°F / 232°C
cotton cloth	513°F / 267°C
rubbing alcohol	750°F / 399°C
pine wood	800°F / 427°C
oak wood	900°F / 482°C

If the temperature of the above fuel materials is kept lower than their ignition point, they will not ignite.

Materials

FOR THE TEACHER

- dollar bill
- 70% isopropyl alcohol (check label on bottle for the percentage)
- water
- cooking tongs
- match or lighter
- clear water glass
- table salt
- tablespoon
- safety goggles
- gloves for the teacher (optional)



Procedure

01 Place the materials on a table for the demonstration so that students can observe the preparation. Identify each item. Tell students you are going to set the dollar bill on fire.

02 Pour 6 tablespoons of the alcohol into the glass. Add 2 tablespoons of water. Add a couple pinches of table salt (to make the flame produced more visible). Stir the mixture.

03 Soak the dollar in the mixture, about five seconds.

04 Using tongs, remove the dollar. Move the glass away from the area where you will ignite the dollar.

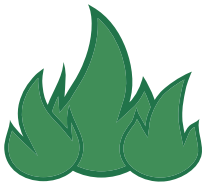
05 Hold up the dollar with the tongs and use a match or lighter to ignite it. A darkened room will help make the flames more visible. After a few seconds, the flame will go out.

06 After the flame goes out, allow students to examine the dollar bill, pointing out that it shows no signs of combustion.

Wrap It Up

- *Why didn't the dollar burn?* The heat produced by the burning alcohol is certainly enough to ignite the dollar bill, but it didn't burn because of the water that was added to the mixture. The water is quickly heated to its boiling point (212°F / 100°C) and becomes a vapor that carries away some of the heat of the burning alcohol. This keeps the temperature of the dollar bill below its combustion point.
- *How does this process help firefighters put out fire?* Water is sprayed onto a burning fuel to lower the temperature of the fuel below its combustion point.

Hess City Fire Department



When the central fire department dispatch center receives a 911 call, which of the city's fire stations is called into action?

Suggested Grades **3–8**

2 Hess City Fire Department

The Question

When the central fire department dispatch center receives a 911 call, which of the city's fire stations is called into action?

Where's the STEM?

One of the goals of a fire department is to get equipment and firefighters to the fire scene while the fire is still small and easier to put out. To achieve this goal, fire trucks use loud sirens and flashing lights to hurry along city streets. These signals are meant to alert other drivers so they can pull over and let the fire trucks pass quickly, ensuring that the firefighters can reach the fire as soon as possible. However, this is not always easy. During busy traffic times, streets can be clogged with vehicles, making it impossible to pull over to the side. Road or lane closures due to construction can also cause problems. Another issue can be the distance to the fire from the nearest fire station.

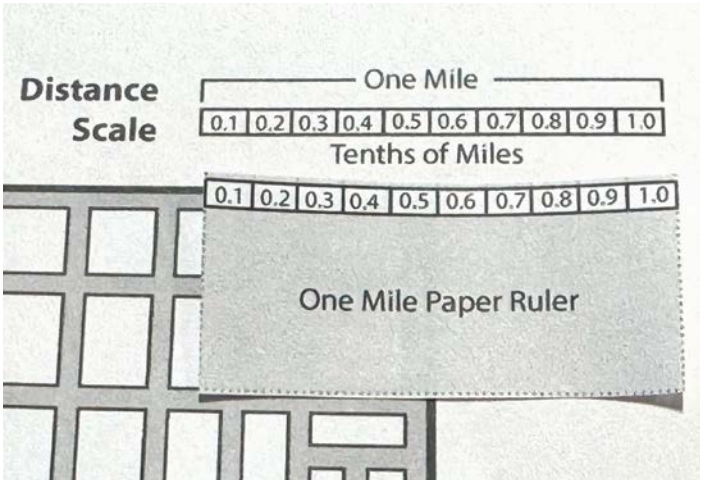
This activity is centered on an imaginary town named Hess City, which has three fire departments. Fire dispatchers decide which fire station will respond to a particular fire based on the distance between the fire and the nearest station. Detailed planning involving maps and measurements is essential to dispatchers. City maps and computer screens are used to visualize the location of the fire and calculate how long it will take fire trucks to arrive. This information helps determine which fire station should respond to the fire. Sometimes the size of a fire requires more than one station to respond.

In this activity, teams of students will play the role of dispatchers by studying the map of Hess City to find the location of the three fire departments (the numbered red boxes) and their distance to potential fires (different-colored boxes marked with letters). Once teams are familiar with the map, have them shuffle the fire cards and draw one card at a time to determine which fire station should be called to action. To do this, teams will use the map and a paper tape measure (see pattern below) to determine the distance of the routes they will use to reach each fire scene.

Materials

PER DISPATCH TEAM

- 2 Hess City maps
- set of Fire Alarm Cards, printed on cardstock
- 2 Hess City paper rulers, printed on cardstock
- several Hess City 911 Fire Dispatch Cards
- marker pen



Management Tips

- Save class time by cutting out the Fire Alarm Cards and two Hess City paper rulers and placing them in envelops for the teams. The size of these rulers might make it difficult for students to cut out themselves.
- Provide two maps for each team to enable all team members to closely examine the map and work together in deciding which fire station to dispatch to the fire described on the card.
- Give several Dispatch Cards to each team and place additional cards in a central location where teams can get more as needed.

Procedure

01 Provide each team with the materials listed above.

02 Review the Dispatch Card instructions with the teams.

03 Next, demonstrate how to measure and record distances with the paper rulers and how to calculate travel times.

04 Explain that because of traffic and community safety, fire trucks travel an average of 20 miles per hour in Hess City. To find out how many minutes it will take to drive to a fire, they will divide 60 (1 minute in seconds) by the speed (20 mph) then multiply that number by the distance in miles. For example, 60 mph divided by 20 mph = 3. Multiply 3 times the distance in miles to get the minutes it will take to reach the fire.

Distance = 0.5 miles 3 x 0.5 miles = 1.5 minutes
Distance = 1.3 miles 3 x 1.3 miles = 3.9 minutes
Distance = 2.5 miles 3 x 2.5 miles = 7.5 minutes

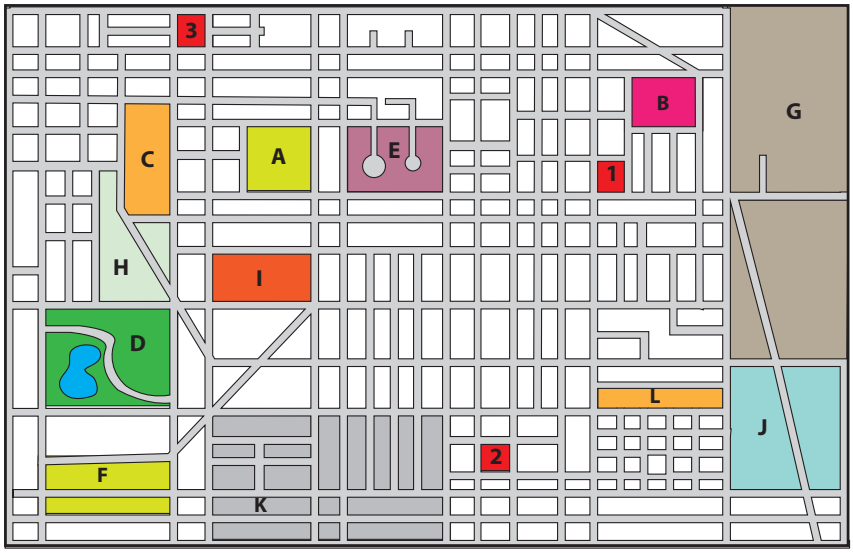
05 Have teams shuffle the Fire Alarm Cards and draw one card. Next, have them locate the fire on the map then write the location and the type of fire on the Dispatch Card.

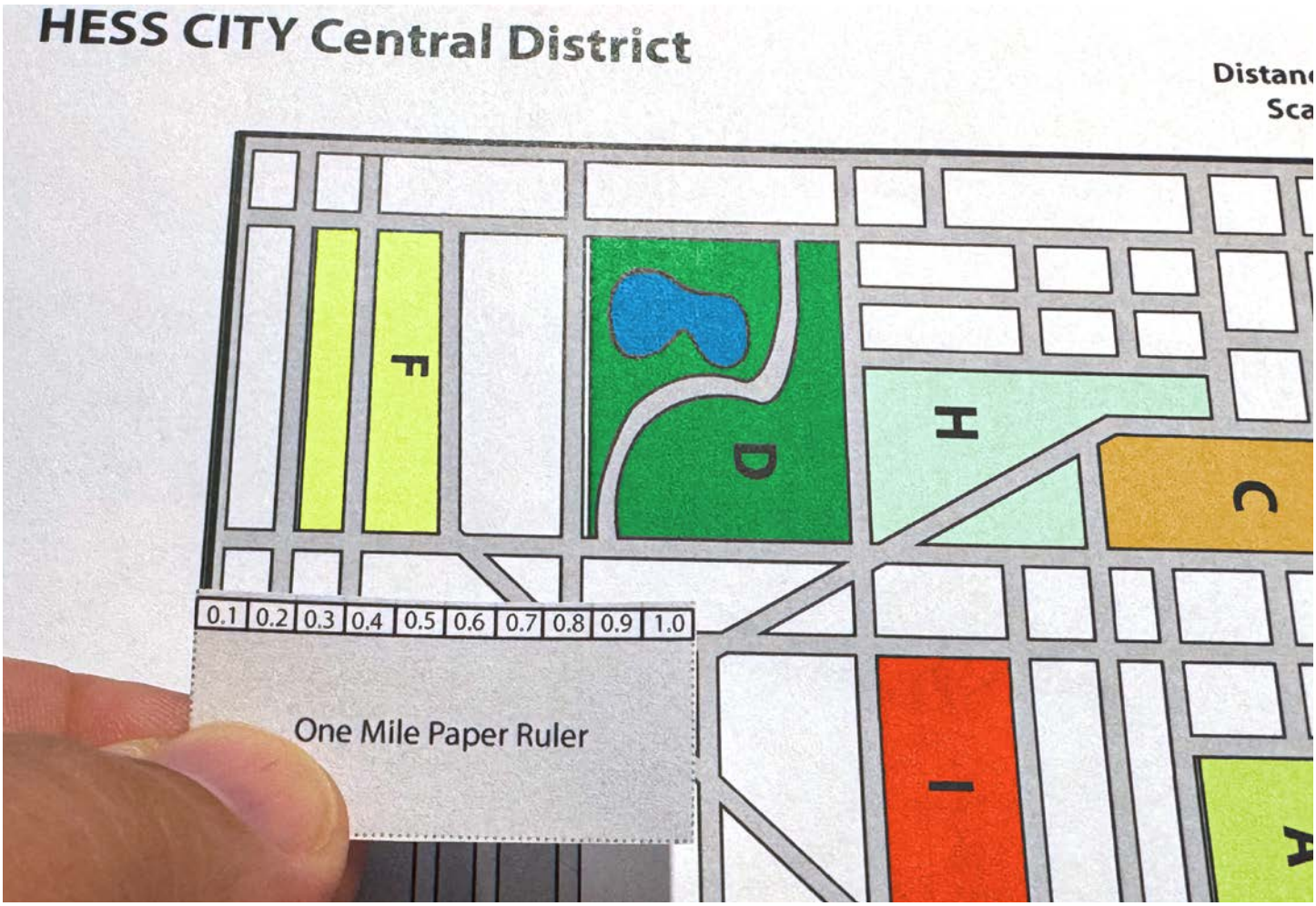
06 Have teams measure and record the distance between the fire and each of the fire departments. Once teams determine which fire department is the closest, have them calculate the time it will take to reach the fire.

07 Repeat these steps for each Fire Alarm Card drawn. Allow time for the teams to respond to several fires.

Note: Some types of fire cannot be extinguished with water, including electrical fires and those involving grease, oil, gasoline, paint, or chemicals. Different types of fire require different types of fire extinguishers. All fire trucks are equipped to handle these various fire types.

A City Hall Complex	B Public Library	C Shopping Mall	G Private Farms - wheat, corn, vegetables
Fire in the records division where thousands of paper file records are kept.	Electrical short in the computer stations sparked a fire in the newspaper collection and the fire spread to the books.	Chemicals in the upscale beauty salon caught fire from an incense candle and fire spread to nearby clothing stores.	Accidental ignition of a gasoline spill when filling a tractor's fuel tank.
H Vacant Lots	**I Distribution Warehouse**	**D Kaeson Park**	**E Shady Glen Cul-De-Sac**
Dry weeds, grass, and trash ignited by a still-burning cigarette butt.	Fire of unknown origin in the furniture section, spreading to household products and toy sections.	A barbecue grill in the picnic area was knocked over when hit by a football. Hot coals landed in dry grass. Nearby trees are on fire.	Gas leak in home led to an explosion, torching the home and spreading to the next door home.
F Paint Factory	**J Future Shopping Complex**	**K Industrial Complex Tire Factory**	**L Strip Shopping Mall**
Lightning strike ignited chemicals in paint waste recycling facility. Nearby paint factory in danger.	Welder's torch ignited construction supplies that spread to unfinished building frames.	Tire storage area on fire due to ignited chemical spill.	Car accident. Car smashed into shop and caught fire.





Wrap It Up

- Project a copy of the Hess City map on a whiteboard. Point out one of the fire locations and ask if any of the teams dispatched a fire truck to fight that fire. From which station was the fire truck dispatched? How far did the fire truck have to travel? How long did it take to get there?
- If more than one team dispatched fire trucks to the same location, compare their results. If they are different, have each team show and explain their chosen route on the whiteboard.
- Ask teams to compare fire-scene arrival times for the three Hess fire vehicles. Each vehicle has its own safe speed when traveling through Hess City. Have students follow the math procedure described in Procedure 4 of the instructions.
    - Fire truck: How many minutes will it take the fire truck to reach a fire 4 miles away if the truck's speed is 20 mph? (12 minutes)
    - Fire chief car: How many minutes will it take the fire chief car to reach a fire 4 miles away if the car's speed is 30 mph? (8 minutes)
    - Fire motorcycle: How many minutes will it take the motorcycle to reach a fire 4 miles away if the motorcycle's speed is 40 mph? (6 minutes)
- Discuss why each vehicle has a different safe operating speed.
- Hess City is experiencing a population growth. In the interest of public safety, the mayor has decided that Hess City needs an additional fire station. Ask students what they think would be the best location for Fire Station 4, and why.

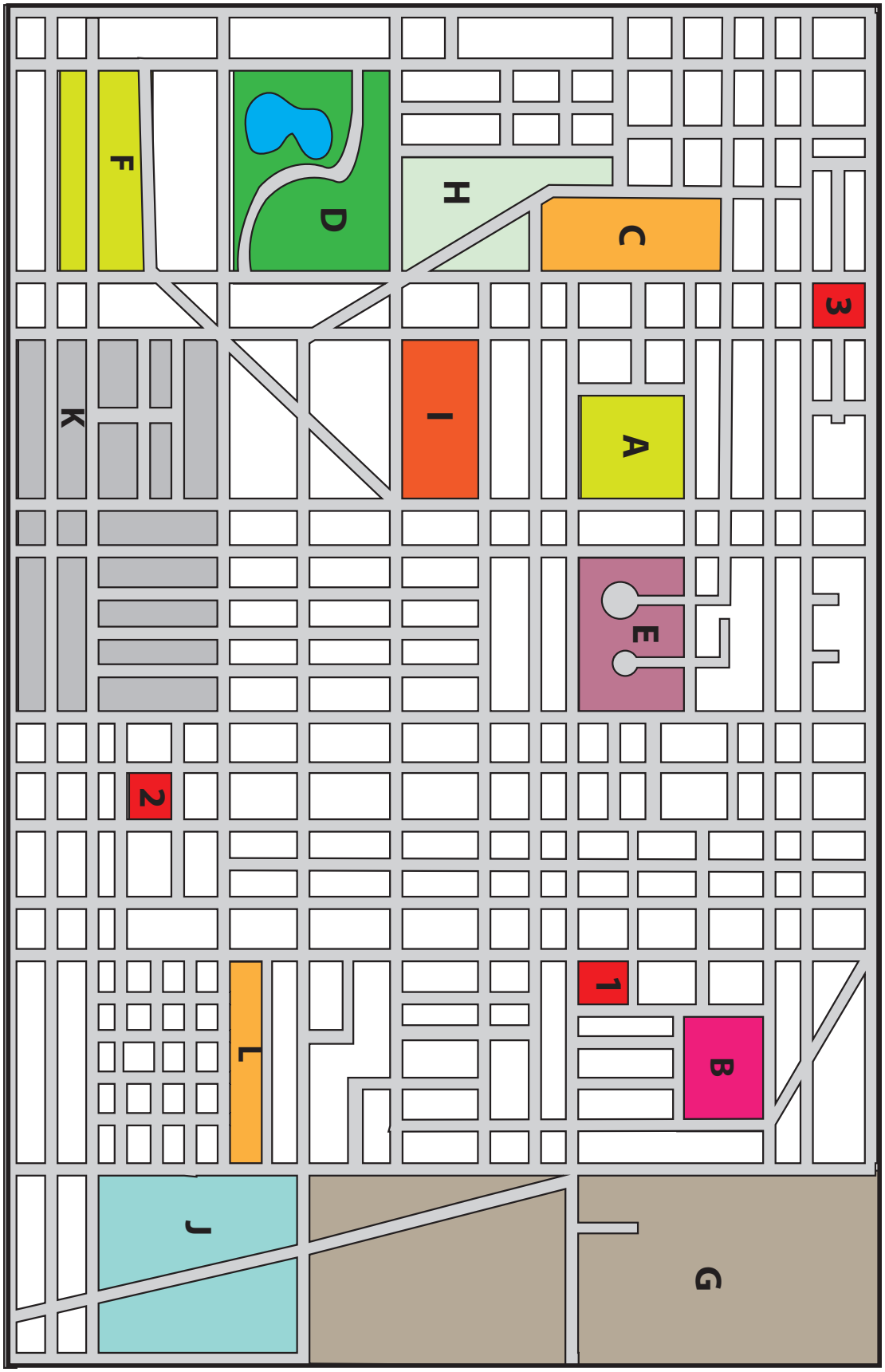
HESS CITY Central District

Distance Scale

One Mile

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Tenths of Miles



Fire Alarm Cards

Print on card stock. Cut out cards and shuffle. Make one set for each team of students.

A City Hall Complex	**B** Public Library	**C** Shopping Mall	**G** Private Farms - wheat, corn, vegetables
Fire in the records division where thousands of paper file records are kept.	Electrical short in the computer stations sparked a fire in the newspaper collection and the fire spread to the books.	Chemicals in the upscale beauty salon caught fire from an incense candle and fire spread to nearby clothing stores.	Accidental ignition of a gasoline spill when filling a tractor's fuel tank.
H Vacant Lots	**I** Distribution Warehouse	**D** Kaeson Park	**E** Shady Glen Cul-De-Sac
Dry weeds, grass, and trash ignited by a still-burning cigarette butt.	Fire of unknown origin in the furniture section, spreading to household products and toy sections.	A barbecue grill in the picnic area was knocked over when hit by a football. Hot coals landed in dry grass. Nearby trees are on fire.	Gas leak in home led to an explosion, torching the home and spreading to the next door home.
F Paint Factory	**J** Future Shopping Complex	**K** Industrial Complex Tire Factory	**L** Strip Shopping Mall
Lightning strike ignited chemicals in paint waste recycling facility. Nearby paint factory in danger.	Welder's torch ignited construction supplies that spread to unfinished building frames.	Tire storage area on fire due to ignited chemical spill.	Car accident. Car smashed into shop and caught fire.

Hess City 911 Fire Dispatch Card

INSTRUCTIONS
Follow the steps below to determine which fire company is best situated to respond to the incident.

Fire Location:_____

Type of Fire:_____

Measure distance to fire for each Fire Company and check box for the closest fire company.

☐ Fire Company 1 _____ miles

☐ Fire Company 2 _____ miles

☐ Fire Company 3 _____ miles

Pick the closest station and calculate how long it will take to arrive if the fire truck can travel 20 mph. _____ minutes

Hess City 911 Fire Dispatch Card

INSTRUCTIONS
Follow the steps below to determine which fire company is best situated to respond to the incident.

Fire Location:_____

Type of Fire:_____

Measure distance to fire for each Fire Company and check box for the closest fire company.

☐ Fire Company 1 _____ miles

☐ Fire Company 2 _____ miles

☐ Fire Company 3 _____ miles

Pick the closest station and calculate how long it will take to arrive if the fire truck can travel 20 mph. _____ minutes

HESS CITY Paper Rulers

One Mile

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Tenths of Miles

Trim paper rulers along the dotted lines

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

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One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

One Mile Paper Ruler

Ladder Lift

How does a fire truck lift, extend, and position its ladder?

Suggested Grades **3–8**

3 Ladder Lift

The Question

How does a fire truck lift, extend, and position its ladder?

Where's the STEM?

There are many kinds of fire trucks, each with a special mission. Some trucks are designed to fight forest fires, some are used for fires in buildings, and some transport water to a fire. For fires located on or near water, there are even fireboats that serve the same functions as fire trucks.

The 2024 Hess fire truck is similar to a special kind of fire truck known as a quint, which combines the ability to transport and spray water and to elevate a long extension ladder that can reach up several floors of a building. "Quint" is short for quintuple, which reflects the truck's five main firefighting tools: a pump, water tank, fire hose, aerial device (extension ladder), and ground ladder.

A quint's multifunctional design makes it useful in many different situations, and it can be effectively operated by fewer firefighters than are needed to operate both an engine truck and a ladder truck. The Hess quint has a cargo area that holds the fire chief car and a motorcycle. On a real quint fire truck, the cargo area holds the water tank, pump, hoses, and other tools needed by the firefighters.

The Hess Fire Truck with Car and Motorcycle allows us to explore many STEM topics, such as energy, force, and motion. In this activity, the mechanism that lifts the aerial ladder will be investigated. A quint's mechanical extension ladder is handy for rescues and spraying water down on hot spots not visible by firefighters on the ground. Making the extension ladder work involves levers and hydraulics systems that use fluids to transmit powerful forces.

Materials

PER INVESTIGATION TEAM

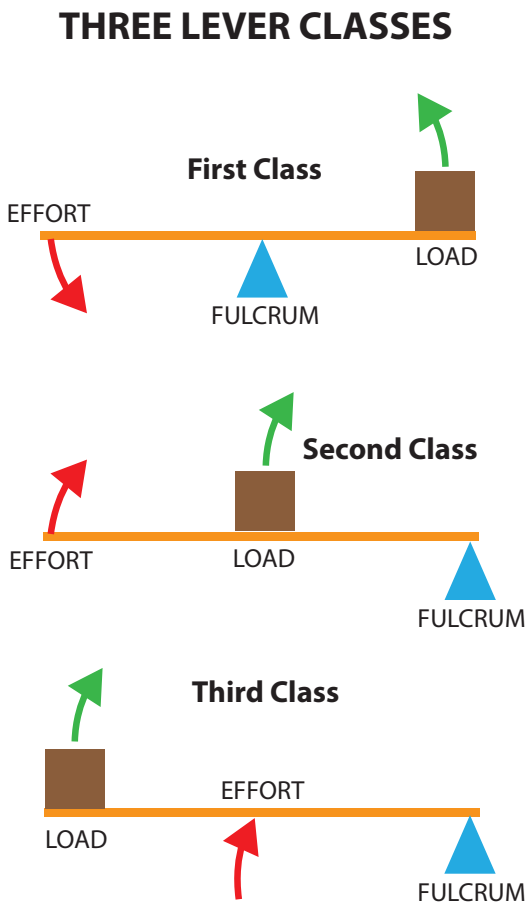
- yard or meter stick
- duct tape
- masking tape
- two 10 mL plastic syringes without needles (syringes can be acquired through Amazon)
- 1-ft. length of standard airline (aquarium) tubing (3/16" inch diameter)
- classroom table
- water
- towels in case of spills
- full 16 oz. water bottle for demonstration

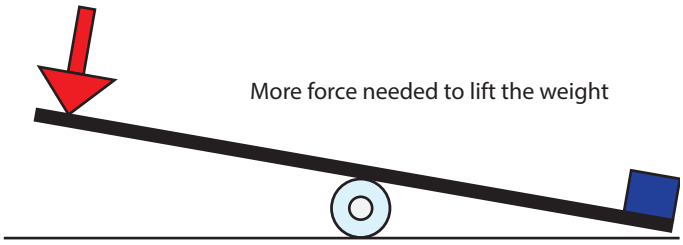
Management Tips

- Begin by describing the three classes of levers (see diagrams below) and how they each transmits force differently to create motion. More information about levers is found in the Hess *Simple and Compound Machines* guide:

  https://www.bioedonline.org/lessons-and-more/focus-on-stem/simple-and-compound-machines/

- First-class levers have the fulcrum placed between the load and effort, second-class levers have load in between the fulcrum and effort, and third-class levers have effort in between the fulcrum and load.
- Explain that by adjusting the position of the fulcrum, large weights can be lifted with less force, but the effort (force) to do this must be expended over a greater distance.
- Using a yard stick or meter stick, demonstrate how levers work. Use tape to affix a small weight at one end of the stick. Place a full water bottle on its side to use as a fulcrum (see image below).
- Position the middle of the stick over the fulcrum and push down on one end of the stick. Point out how the downward distance of the effort (push) is the same as the upward distance of the load.

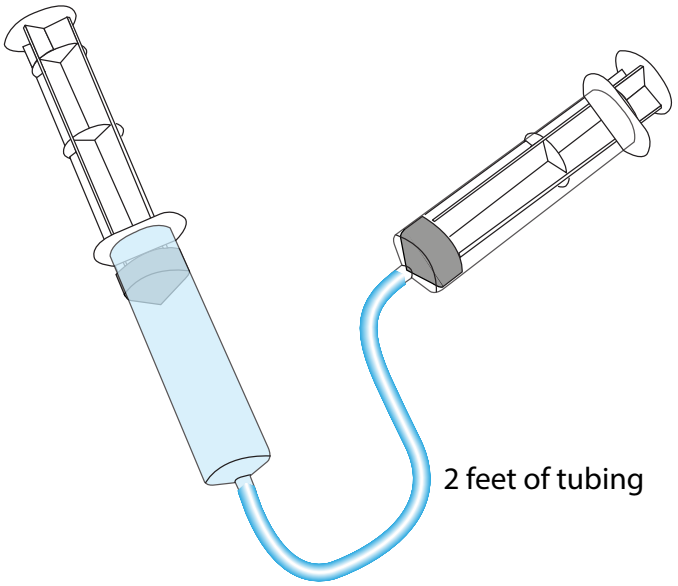




- Next, slide the fulcrum closer to the load and repeat. Point out how the downward distance of the effort (push) is greater than the upward distance of the load.

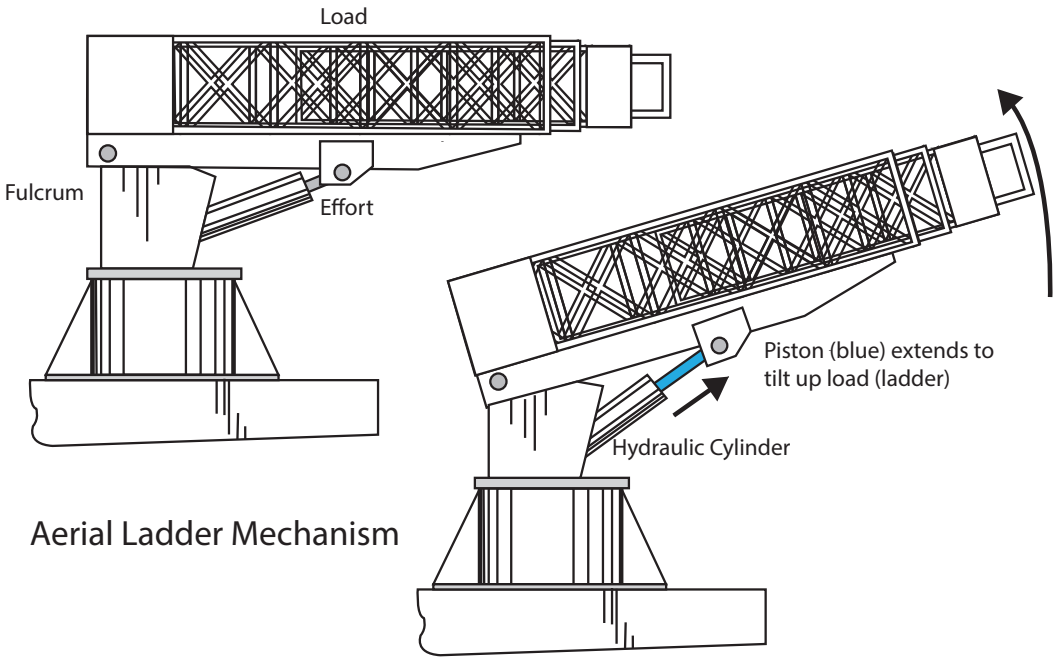
Management Tips Continued

How to Conduct the Ladder Lift Activity



- Prefill the hydraulic systems for each team. Connect one end of the aquarium tubing to the end of a plastic syringe (plunger compressed).
- Submerge the syringe and tubing in a bowl of water or a water-filled sink; fill the syringe with water by pulling the plunger outward.
- Connect the other end of the tubing to the end of the second syringe (plunger compressed) The hydraulic system is ready to use.
- **Pushing** on the plunger of the water-filled syringe will force the plunger of the empty syringe to extend as it fills with water. **Pulling** the first plunger back will cause the other plunger to move back into its syringe.

- Point out that the aerial ladder on a Hess Fire Truck is raised when a piston in a hydraulic cylinder extends. Reinforce the concept of how a lever works by pointing out where the load, fulcrum, and effort are on the aerial ladder.



Aerial Ladder Mechanism

- Explain that each investigation team will make their own version of an aerial ladder that works by hydraulics.

Procedure

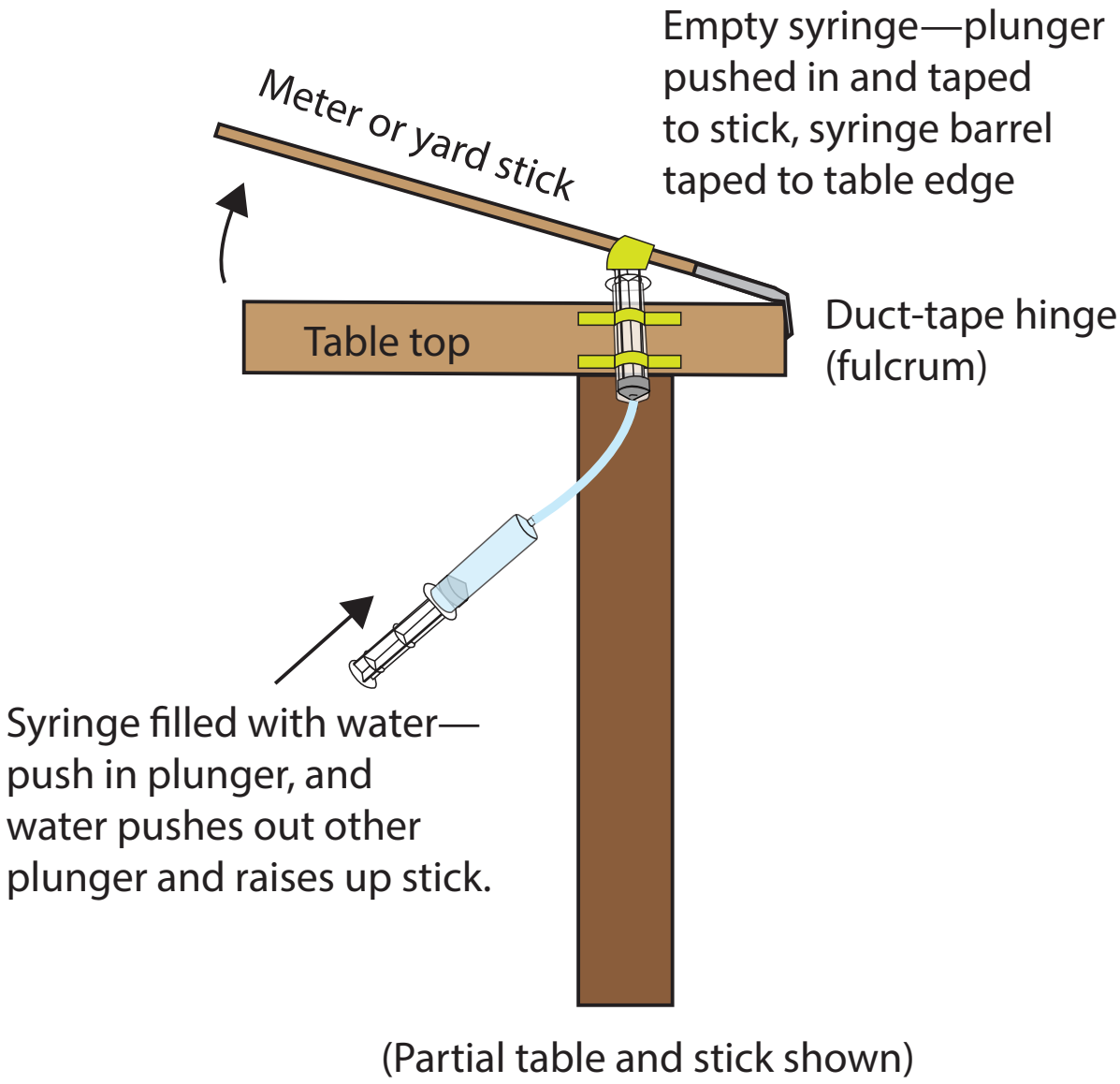
01 Prepare the hydraulic system of syringes as described in the Management Tips section. Use masking tape to secure the empty syringe (the plunger pointing upward) to a table's edge, as shown in the diagram below.

02 Use duct tape to make a hinge for either end the meter or yard stick at the edge of the table. The stick should lift up and pivot with the hinge.

03 Use masking tape to attach the plunger of the empty syringe to the measuring stick as shown below.

04 Slowly compress the plunger of the water-filled syringe to force water through the aquarium tube and into the empty syringe. The empty syringe will start filling water and the piston will push out from the barrel, lifting the measuring stick.

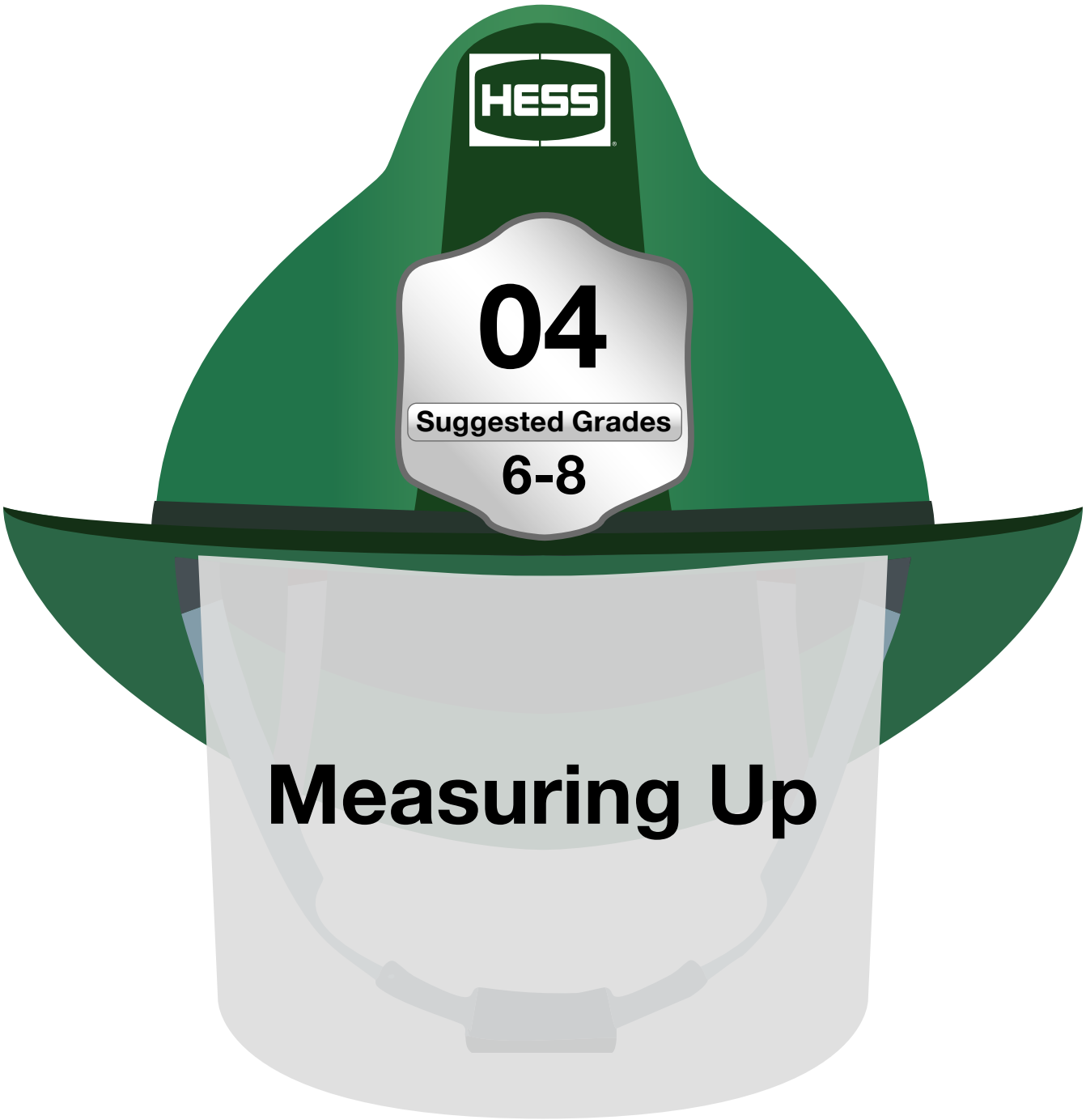
05 Slowly pull out the plunger of the now empty syringe and the measuring stick will lower. This is the general way the aerial ladder on a fire truck works.



Wrap It Up

- *What kind of lever is a fire engine aerial ladder?* The ladder is a third-class lever. The fulcrum is located at the lower end of the ladder, the effort is the hydraulic piston near the fulcrum, and the load is the ladder itself.
- *How can our model of the aerial ladder be made to rise higher?* One way is to have a longer piston (represented by the syringe plunger) in the hydraulic cylinder (represented by the syringe) so that it extends further and raises the ladder higher. The other way is to have the hydraulic cylinder very close to the fulcrum so that a small movement in the piston becomes a large movement of the ladder's upper end. This requires a very powerful effort force that the hydraulic cylinder can provide.
- *Does the force needed to raise the ladder change if the ladder is extended to its full length?* Yes. The long ladder exerts more downward force on the hydraulic cylinder. Demonstrate this by giving a student a heavy book to hold close to their chest and then with their arms fully extended. How hard is it to hold up the book near the chest vs. holding it out at arm's length?

- **Discussion topic:** *If the fire crew has to reach a very high fire, should they extend the ladder and then lift it, or should they lift the ladder to the right angle and then extend it?* In situations where the fire crew needs to reach a very high fire, it's generally more effective to extend the ladder first and then lift it into position. This approach allows for better control and stability as the ladder is extended to the desired height. Lifting the ladder to the right angle before extending it can be more challenging and may increase the risk of losing balance.



Measuring Up

How high can a ladder reach based on its angle?

Suggested Grades **6–8**
Advanced

4 Measuring Up

The Question

How high can a ladder reach based on its angle?

Where's the STEM?

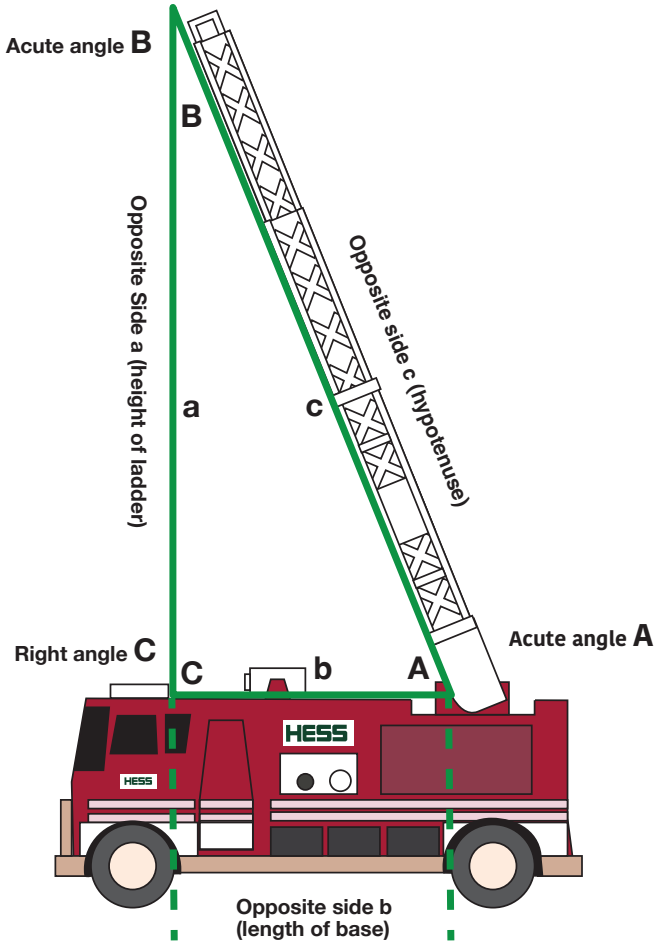
Fire truck aerial ladders are intended for structural fires, such as those that can occur with multistory buildings. The fire truck driver parks the truck near the burning building and the ladder operator activates the hydraulic-lift system to raise the ladder to the appropriate angle, extend all the ladder's sections, and swing the ladder's upper end to the roof or a chosen window. The operator needs a thorough understanding of how to work the controls and what the ladder is capable of—specifically, how high the ladder can reach based on its angle.

When the ladder is deployed, it forms a right triangle because one of the interior angles is 90 degrees. The three sides of the triangle are marked a, b, and c in the illustration.

The long side (c) of the triangle forms the hypotenuse. The second side (a) is the distance directly above the spot on the ground where the upper end of the ladder reaches. This makes a vertical line extending upward at a 90-degree angle from the ground. The third side of the triangle (b) is the distance from the spot on the ground to the fulcrum of the ladder (the point where the ladder pivots or balances).

By knowing the length of the ladder and the length of the ladder's base, the height of the ladder can be calculated. The calculation employs the Pythagorean Theorem, which states that the square of the hypotenuse (longest triangle side) is equal to the sum of the squares of the opposite two sides. In other words,

$$c^2 = a^2 + b^2$$



Where's the STEM? Continued

If the length of c (the ladder extended) is known and the length of b (base) is known, the length or altitude of the vertical side can be calculated. The equation is

$$a = \sqrt{c^2 - b^2}$$

There are other ways of calculating the height of the ladder based on its tilt angle. One method is the use the tangent function from trigonometry. The tangent of an acute angle in a right triangle is the ratio (comparison) of the length of the side opposite the angle (side **a** in the illustration) to the length of the side adjacent to it (side **b** in the illustration).

Tangent ratios for acute angles are found in the "Tangent Ratios" table. A larger version of the table is found on the pages that follow.

To calculate the height of the ladder, the following equation is used:

height (a) = tangent angle A times base b

or

a = tan A x b

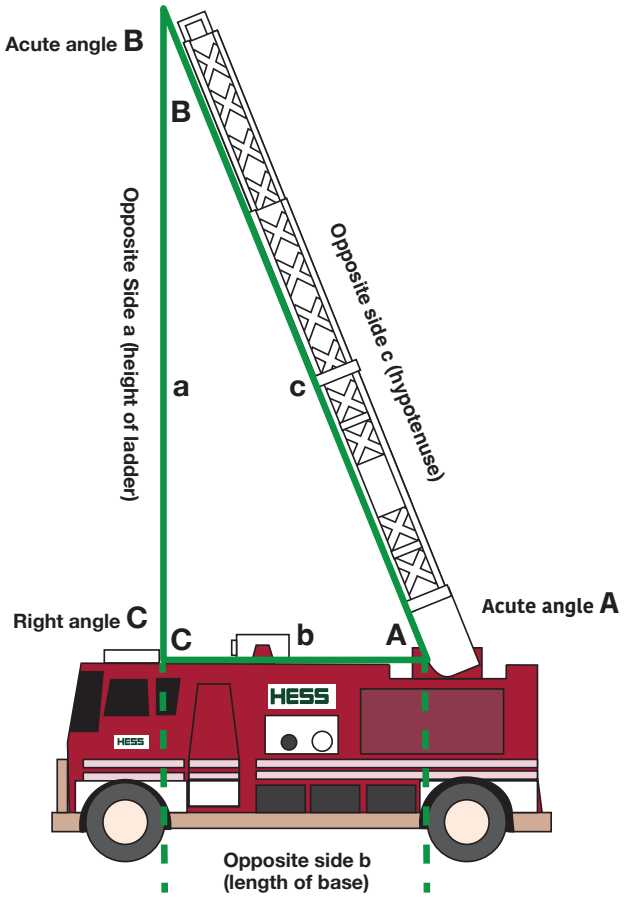
For example, if acute angle a is 35 degrees, tan a is 0.7002 (see "Tangent Ratios" table). Base b is 20 feet. Therefore,

c = 0.7002 x 20 feet = 14.004 feet

Tip: Don't forget the height of the truck itself. Add that measurement to the answer for the actual height of the top of the ladder.

Tangent Ratios

Angle°	Tangent	Angle°	Tangent
0	.0000	46	1.036
1	.0175	47	1.072
2	.0349	48	1.111
3	.0524	49	1.150
4	.0699	50	1.192
5	.0875	51	1.235
6	.1051	52	1.280
7	.1228	53	1.327
8	.1405	54	1.376
9	.1584	55	1.428
10	.1763	56	1.483
11	.1944	57	1.540
12	.2126	58	1.600
13	.2309	59	1.664
14	.2493	60	1.732
15	.2679	61	1.804
16	.2867	62	1.881
17	.3057	63	1.963
18	.3249	64	2.050
19	.3443	65	2.145
20	.3640	66	2.246
21	.3839	67	2.356
22	.4040	68	2.475
23	.4245	69	2.605
24	.4452	70	2.747
25	.4663	71	2.904
26	.4877	72	3.078
27	.5095	73	3.271
28	.5317	74	3.487
29	.5543	75	3.732
30	.5774	76	4.011
31	.6009	77	4.331
32	.6249	78	4.705
33	.6494	79	5.145
34	.6745	80	5.671
35	.7002	81	6.314
36	.7265	82	7.115
37	.7536	83	8.144
38	.7813	84	9.514
39	.8098	85	11.43
40	.8391	86	14.30
41	.8693	87	19.08
42	.9004	88	28.64
43	.9325	89	57.29
44	.9657	90	---
45	1.000	---	---



Materials

PER INVESTIGATION TEAM

- 2024 Hess fire truck
- ruler or tape measure
- calculator or calculator app on smart phone
- plastic protractor (or students can use the paper protractor in the "Off-Road Hill Climb" activity)
- copy of the "Tangent Ratios" table below.

Procedure

Method 1

01 Extend the ladder on the Hess fire truck to its full length and measure how long it is. This is the hypothenuse of the right triangle (c).

02 Measure the base of the ladder (b) from the fulcrum (acute angle A) to a point directly below the upper end of the ladder (acute angle C).

03 Calculate the height of the ladder top (a) with the following equation:

$$a = \sqrt{c^2 - b^2}$$

04 Measure the height of the fire truck (from the tires to the top of the truck) and add this to your answer to get the actual altitude of the ladder top.

05 Check your results by using a ruler or tape measure to measure the from the top of the ladder to your tabletop to confirm your answer in step 5.

06 Using a protractor to measure the angle of the ladder, calculate how high the ladder reaches at different angles, such as 30, 50, and 75 degrees.

Method 2

01 Change the tilt (acute angle A) of the ladder and use a protractor to measure this angle at the roof of the fire truck.

02 Use the "Tangent Ratios" table to find the tangent number for the angle you just measured. (To do so, locate the number for the angle in the "Angle" column; the tangent number is directly to the right of the angle number in the corresponding "Tangent" column.)

03 Measure the length of the base (b).

04 Now, calculate the height of the ladder (a) with the following equation:

$$a = \tan A \times b$$

Note: a is the calculated height of the ladder, **tan A** is the number from the "Tangent Ratios" table, and **b** is the length of the base.)

05 Confirm your answer by actually measuring the height of the ladder at it's highest point. Remember to add the height of the fire truck to your answer.

Wrap It Up

- *Why is it important for the fire chief and fire crew to know the department's firefighting equipment capabilities?* Firefighters need to know how things work to quickly and efficiently put out fires to save property and lives.
- *What happens to the length of the base (b) when the angle of the ladder is changed?* When the angle of the ladder changes, particularly when the slope decreases, the base length (b) increases. This is because the ladder stretches out more horizontally as the angle decreases.

Tangent Ratios

Angle°	Tangent	Angle°	Tangent
0	.0000	46	1.036
1	.0175	47	1.072
2	.0349	48	1.111
3	.0524	49	1.150
4	.0699	50	1.192
5	.0875	51	1.235
6	.1051	52	1.280
7	.1228	53	1.327
8	.1405	54	1.376
9	.1584	55	1.428
10	.1763	56	1.483
11	.1944	57	1.540
12	.2126	58	1.600
13	.2309	59	1.664
14	.2493	60	1.732
15	.2679	61	1.804
16	.2867	62	1.881
17	.3057	63	1.963
18	.3249	64	2.050
19	.3443	65	2.145
20	.3640	66	2.246
21	.3839	67	2.356
22	.4040	68	2.475
23	.4245	69	2.605
24	.4452	70	2.747
25	.4663	71	2.904
26	.4877	72	3.078
27	.5095	73	3.271
28	.5317	74	3.487
29	.5543	75	3.732
30	.5774	76	4.011
31	.6009	77	4.331
32	.6249	78	4.705
33	.6494	79	5.145
34	.6745	80	5.671
35	.7002	81	6.314
36	.7265	82	7.115
37	.7536	83	8.144
38	.7813	84	9.514
39	.8098	85	11.43
40	.8391	86	14.30
41	.8693	87	19.08
42	.9004	88	28.64
43	.9325	89	57.29
44	.9657	90	---
45	1.000	---	---

"Tanker" Fire Truck

How does the weight of water carried by the “tanker” fire truck affect the energy needed to move the truck from one place to another?

Suggested Grades **4–8**

5 "Tanker" Fire Truck

The Question

How does the weight of water carried by the "tanker" fire truck affect the energy needed to move the truck from one place to another?

Where's the STEM?

The 2024 Hess Fire Truck with Car and Motorcycle is designed to enhance the versatility of the Hess Firefighting Company. In real-life firefighting, tanker fire trucks play a crucial role. These trucks are equipped with large water tanks and are essential in areas where hydrants are not available. Tanker fire trucks transport significant amounts of water to the site of a fire, enabling firefighters to combat flames effectively. However, this increased water weight requires more energy to move the truck.

In this activity, teams will use the Hess fire truck to investigate how a tanker truck works. Specifically, they will explore how the added weight of the water affects a tanker truck's mobility and speed. Because the Hess fire truck does not have its own motor, the fire chief car will substitute for the truck's motor. The fire chief car uses a pull-back motor with a windup spring and gear system to store potential energy that converts to kinetic energy when released.

Using different weights to simulate the water load, teams will conduct tests to observe the effects of weight on motion and learn about energy transfer as they measure the distance traveled by the truck.

Materials

PER INVESTIGATION TEAM

- 2024 Hess fire chief car
- 2024 Hess fire truck
- weights (e.g., small metal washers, coins, or other small objects)
- ruler or measuring tape
- calculator (optional)
- masking tape
- paper and pencils
- 2–3 ft. (0.61 – 0.91 m) of string
- flat sheet of cardboard or poster board for creating a smooth testing surface (optional)
- "Tanker Fire Truck Investigation" data sheet

FOR THE CASS

- balance scale or kitchen scale

Management Tips

- Set up a weighing station with a balance scale or kitchen scale.
- Find adequate space to set up 3 testing areas on the floor (see diagrams below for layouts).
- Provide easy access to measuring materials and weights to be used in testing.
- Make copies of the "Tanker Fire Truck Investigation" page for each team.

Procedure

01 Divide class into teams of 2–3 students.

02 Explain that teams will use the Hess fire truck to represent a tanker fire truck that carries water to a fire. Instead of water, students will use weights in the investigation.

03 Tell them that because the Hess fire truck has no motor, they will use the Hess fire chief car to pull it. To properly engage the spring motor in the fire chief car, push down on the car while pulling it back across the floor. The friction between the wheels and the floor causes the wheels to rotate backward. A system of gears, connected to the wheels, transfers kinetic energy to the spring by winding it. When the motor clicks, the spring is fully charged with potential energy. These concepts of kinetic and potential energy are more fully explained in the Hess *Science of Speed* guide:

https://tinyurl.com/BioEdSciSpeed

Allow students a few minutes to explore the capabilities of the toy fire truck and the car's pull-back motor.

04 Show students the fire truck's back compartment where the weights will be added.

05 To begin, have teams measure the volume of the truck's back compartment where the fire chief car is stored. (Do not include the motorcycle compartment.) They will need to measure its length, width, and height, then record their measurements on the "Tanker Fire Truck Investigation" data sheet. **Note:** the size of the fire truck's compartment is 15.2 cm long, 7.6 cm wide, and 5.1 cm high (5.98 inches long, 2.99 inches wide, and 2 inches high).

06 Have students calculate the volume of the compartment using the formula below:

Volume = Length x Width x Height

The calculated volume should be approximately 580 cubic centimeters (approximately 35.39 cubic inches). Record the volume on the data sheet.

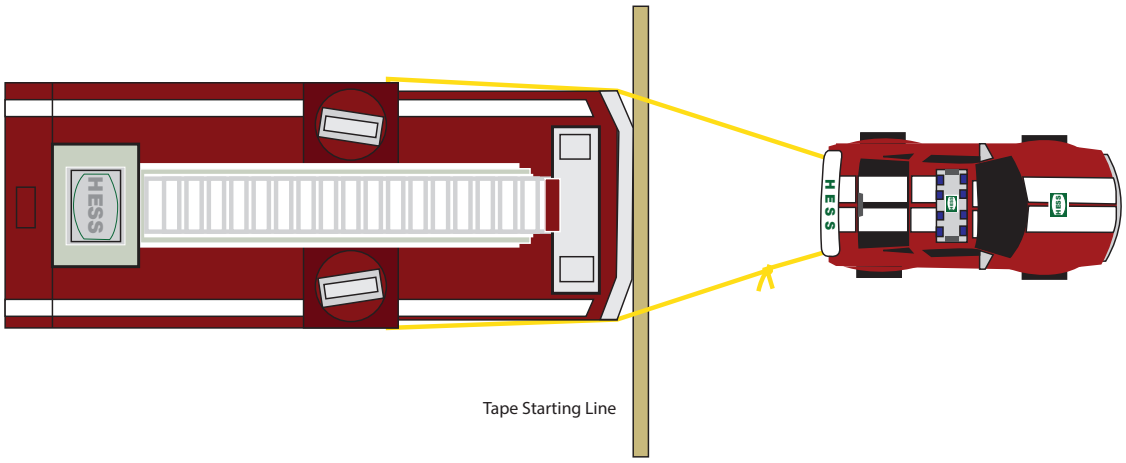
07 Next, students will calculate the weight of the compartment if it were filled completely with water. **Note: Do not actually put water in the compartment!** Water has a density of approximately 1 gram per cubic centimeter (g/cm^3). Therefore, the weight of the water can be calculated by finding the volume in cubic centimeters and converting it directly to grams. One gram is equivalent to 1 cubic centimeter. Thus, the weight of the water = 580 grams (20.45 ounces). Record the calculated weight on the data sheet.

08 Show teams how they will tie the fire chief car to the fire truck using a string loop about 25–30 centimeters (~10–12 inches) in diameter.

09 Before tying the loop, first run the string through the truck's storage compartment and close the doors. Once the string is in place, loop the other end of the string over the spoiler on the back of the fire chief car (see diagram below).

10 Mark a starting line on the floor with masking tape. Ensure that the testing surface is flat and smooth to minimize friction. Use a sheet of cardboard or poster board if necessary.

11 Place the truck's front wheels on the tape line and position the car in front with the string taut.



12 Begin the first test without adding any weight to the truck. Pull the fire chief car backward until it clicks to wind up the spring motor. Release the fire chief car and measure the distance the truck travels from the tape line to the position of the truck's front wheels. Record the measurement on the data sheet. (If the truck does not move, lightly nudge the rear of the truck to overcome its inertia.)

13 Repeat this test 2 more times, recording the distance the truck travels for each test and then averaging the 3 distances.

14 Next, teams will add weights to the truck compartment. Use whatever materials you have (paper clips, coins, etc.).

15 Teams will go to the weighing station and measure out 50 grams (1.7 ounces) of materials for the second test. They will run the test 3 times, recording the distances traveled by the truck and then averaging the 3 distances.

16 Repeat using 100 grams (3.5 ounces) of materials for the next 3 tests and 150 grams (5.29 ounces) for the last 3 tests. Record all measurements on the data sheet.

17 After completing all testing, have students analyze their data. What do they notice? Have them create a graph showing the relationship between the weight added to the fire truck and the distance traveled by the truck.

Wrap It Up

- Ask teams to report their results and compare findings. Connect the findings to real-world situations where fire trucks carry water to put out fires, and discuss how this affects their operations.
- Discuss how added weight affects the distance traveled. *What does this tell us about the amount of energy needed to move the fire truck?* The heavier the load, the more energy it takes to pull it. The addition of extra weight or mass means that the truck has greater inertia or resistance to a change in motion (Isaac Newton's first law of motion. See Glossary.)
- *Why do you think the fire truck moved slower when we added more weight?* The increased mass requires more force to accelerate. Additionally, the added weight increases friction between the tires and the floor, which can slow down movement. More weight also means the engine has to work harder to maintain speed, leading to slower acceleration and reduced overall speed.
- *How do real firefighters deal with heavy water tanks when they are driving to a fire?* Real firefighters use specially designed fire trucks with powerful engines to handle the added weight. Additionally, some trucks have features like air brakes and automatic transmission systems to assist with controlling the vehicle under heavy loads.
- As an extension, connect several fire chief cars with the string loops to see how performance is improved with a "bigger engine."

Tanker Fire Truck Investigation

Team Member Names

_____ _____

_____ _____

INSTRUCTIONS

Use the Hess fire chief car to move the tanker truck. Tie a string loop to connect the fire truck to the chief's car.

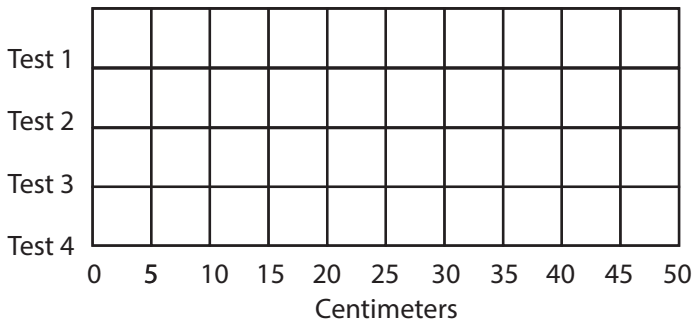
- Power up the chief car and tow the tanker.
- Measure how far the tanker is pulled from the starting tape line.
- Repeat the investigation, but add 50 grams of weight to the tanker compartment.
- Repeat again with 100 and then 150 grams.
- Record your results below.
- Average the results for each test.
- Construct a graph to show the relationship between the load the truck carries and the distance it travels.

DATA

	Distance Traveled Test 1	Distance Traveled Test 2	Distance Traveled Test 3	Average Distance Traveled
Tanker Truck Empty				
Tanker Truck + 50 grams				
Tanker Truck + 100 grams				
Tanker Truck + 150 grams				

Plot your average results for the 4 tests. Put a dot on the horizontal test line showing the distance traveled. When done, connect the 4 dots with a solid line.

What does this line tell you? Put your answer on the back of this page.



Off-Road Hill Climb

How will the performance of two distinct power systems compare when the fire chief car and motorcycle navigate steep slopes?

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

6 Off-Road Hill Climb

The Question

How will the performance of two distinct power systems compare when the fire chief car and motorcycle navigate steep slopes?

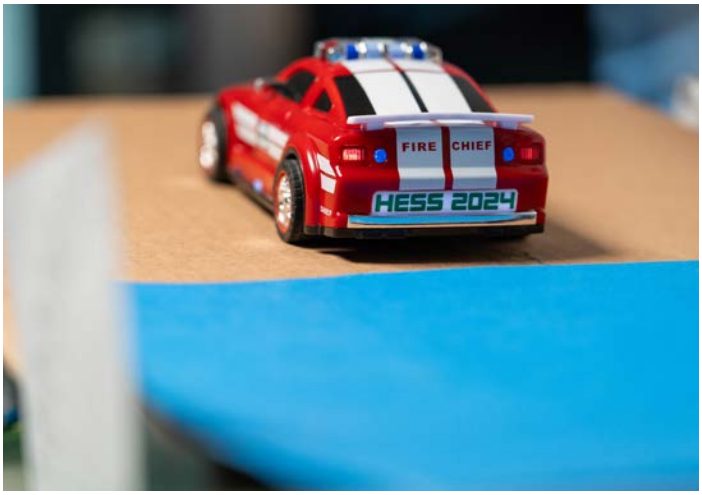
Where's the STEM?

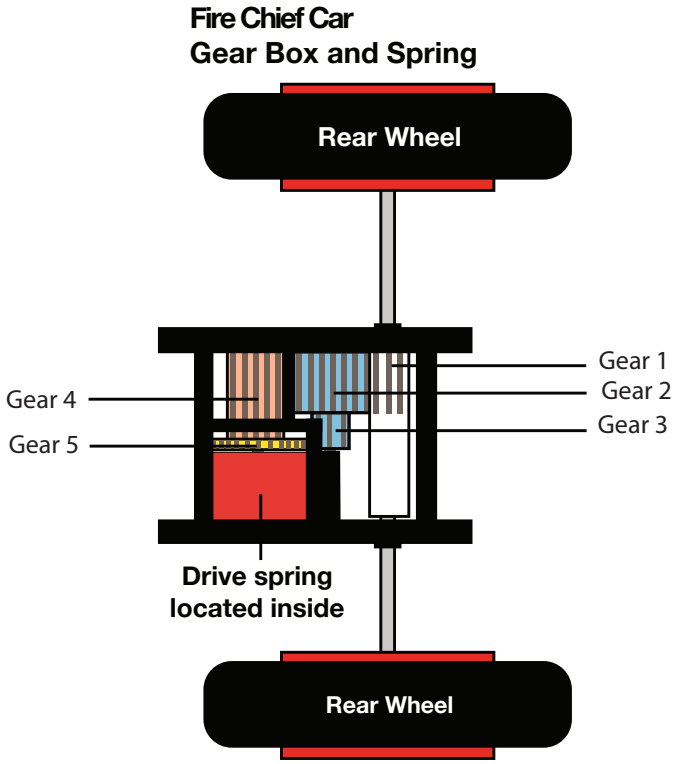
Both the fire chief car and the motorcycle included with the 2024 Hess Fire Truck with Car and Motorcycle are designed to enhance the versatility of the Hess firefighting team. Although real-life versions of these vehicles can handle rough terrain, the Hess toys are designed to operate on smooth types of flooring, including linoleum, low-pile carpeting, and concrete. Operating the toys on sand, dirt, or anything that might damage their inner workings should be avoided.

The fire chief car has working headlights and taillights, and red, white, and blue safety lights. But the most important part of the car is its propulsion system. It has a pull-back motor that uses a windup spring and gear system to store potential energy that is then converted to kinetic energy, or the energy of motion, when released.

Rolling the car backward along a smooth surface several times will wind the spring as the gears connected to the rear wheels rotate. When the spring is fully wound and has stored all the potential energy it can hold, it produces a clicking sound. At that point, release the car. As the spring unwinds, it rotates the gears that power the wheels, converting the stored energy into kinetic energy. This gives the fire chief car a fast start.

The gears in the fire chief car are colored in the diagram below to make them easier to see. In the actual gearbox, all the gears are white. (**Please do not open the gearbox for examination!** This may damage the gears and the functionality of the chief car and the motorcycle.)





(Bottom view)

Where's the STEM? Continued

The motorcycle has a different power system. Instead of a windup spring motor, it is powered by a geared flywheel. A flywheel is a disk commonly attached to a rotating shaft. The flywheel's momentum makes it more resistant to changes in rotational speed, which helps keep the shaft rotating at the same speed longer. This is a simple mechanical means of storing energy.

To engage the flywheel, the motorcycle needs to be pushed quickly forward across a flat surface. Friction with the surface causes the rear wheel to spin. The rear wheel is connected by internal gears that increase the rotation rate and transfer kinetic energy to the flywheel, which spins very rapidly. When the motorcycle is released, the kinetic energy of the flywheel is transmitted back to the rear wheel, propelling the motorcycle forward and making a motor like whining sound.

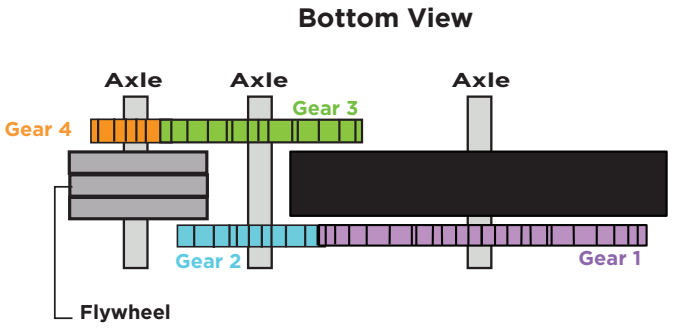
As shown in the illustration, the motorcycle's gears are arranged in two step-up systems, which means the gears have different diameters. The rear wheel is directly connected to gear 1 (purple) along the rear wheel axle. Pushing the motorcycle causes the rear wheel and gear 1 to rotate counterclockwise.

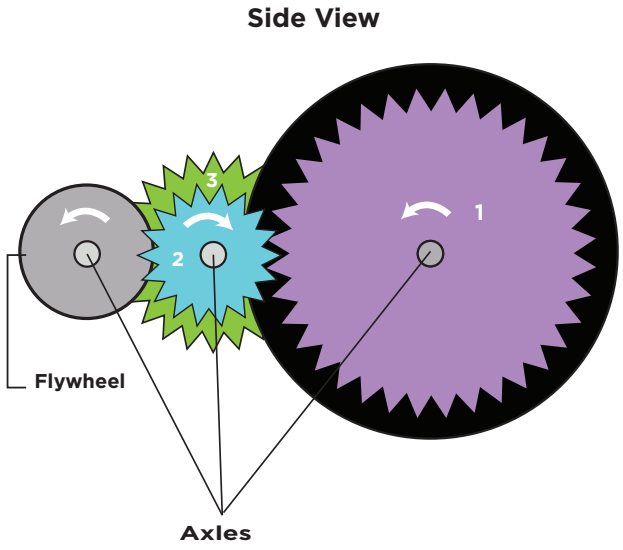
The teeth, or cogs, of gear 1 mesh with those of gear 2 (blue). Gear 1 has 36 teeth. Gear 2 has 18 teeth. Thus, the gear arrangement "steps up" (or doubles) the rotational speed of gear 2, which rotates clockwise twice as gear 1 rotates once.

Gear 2 (blue) is directly connected to gear 3 (green) by the axle. As a result, gear 3 also rotates twice with each rotation of gear 1. Gear 3 has 20 teeth that mesh with gear 4 (orange, seen in "Bottom View"). Because gear 4 has 10 teeth, it rotates counterclockwise twice for every rotation of gear 3.

There is one more part to this system: the axle for gear 4 also holds a metal disk known as a flywheel. The purpose of the step-up gear system is to rotate the flywheel very fast, thereby loading the flywheel with kinetic energy.

So, how will these two distinct power systems compare as the vehicles navigate steep slopes? What is the maximum slope angle they can successfully navigate?





Gear 1 = 36 teeth
Gear 2 = 18 teeth
Gear 3 = 20 teeth
Gear 4 = 10 teeth (not shown in side view)

Materials

PER INVESTIGATION TEAM

- 2024 Hess fire chief car
- 2024 Hess motorcycle
- 2 or 3 sheets of cardstock
- flat sheet of cardboard or poster board
- plastic protractor (or students can make paper protractors; see "Protractor Pattern" below)
- masking tape
- stacks of books
- scissors
- "Hill Climb" data sheet

Management Tips

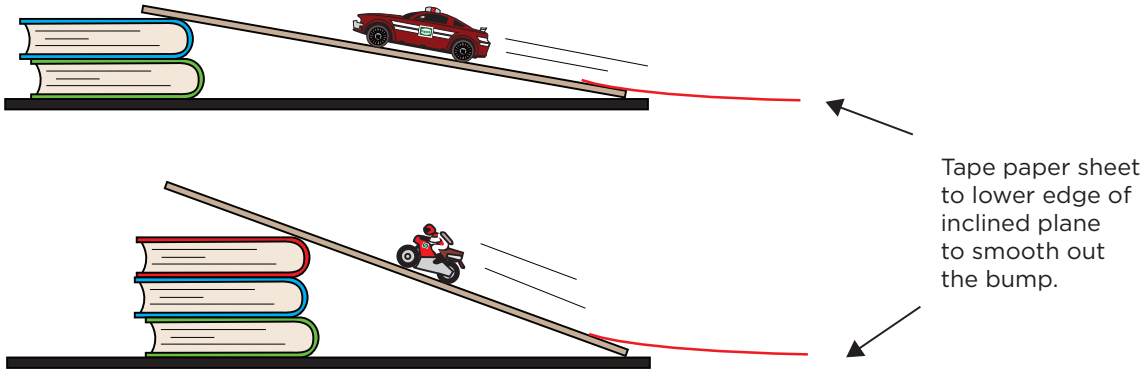
- Before beginning the activity, use the information and illustrations provided above to explain the two different power systems and the sequence of kinetic-potential-kinetic energy in both vehicles. Also demonstrate how to wind up each vehicle. **Note:** For younger children, a detailed explanation of the power systems may not be necessary. Simply demonstrate how to wind up the vehicles and proceed to testing.
- Be sure there is adequate floor space for teams to set up their slopes without interfering with other teams. Testing on a flat, smooth surface will also ensure more consistent results. (You may want to create a system for adjusting the slopes so students can quickly test different angles without having to rebuild the ramp each time, e.g., each team builds a specific ramp angle and teams rotate to different stations.)
- Remind the teams that the fire chief car must be rolled backward on a hard surface until a clicking sound is heard to be fully wound. The clicking sound means the car spring is fully loaded with potential energy. The spring can be wound using one long pull or several short pulls.
- Tell them it is important to keep the rear wheels from spinning when the car is repositioned at the starting line. To prevent the rear wheels from turning, pull the car backward and then press a finger on one wheel to hold the wheels in place.
- Moving the motorcycle requires quickly pushing it forward across a flat surface. The push should start behind the starting line, with the motorcycle released at the starting line.

Procedure

01 Allow the teams a few minutes to explore the toys' capabilities.

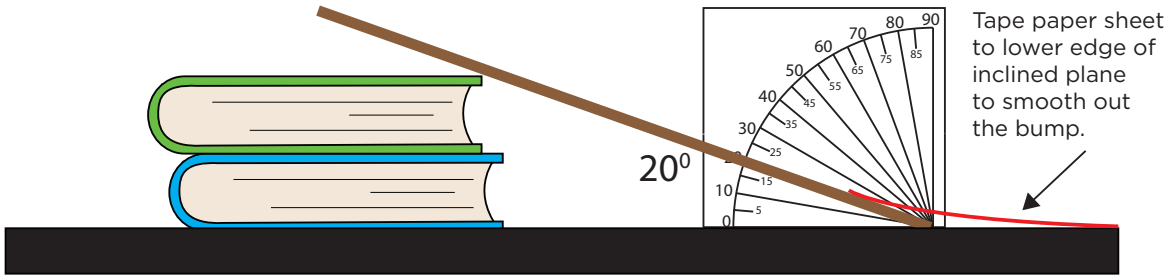
02 Pose this question: How will the two different power systems compare when they navigate slopes? Challenge teams to determine the highest slope angle either vehicle will be able to navigate.

03 Place a stack of books on the floor and lean one end of the cardboard sheet on top of the stack (see illustrations below). This creates a "hill" or slope for the vehicles.



04 The slope angle can be adjusted by sliding the books toward or away from the base of the slope. Instruct teams to tape cardstock to the base of the cardboard slope and to the floor to smooth the bump where the floor and cardboard meet.

05 Explain and demonstrate how they will use a protractor to measure the angles. Then, have teams cut out the protractor pattern (if using) and assemble and tape the flaps to make it stand up. (See directions on illustrations.) If preferred, regular plastic protractors can be substituted for the paper ones.



* For illustration purposes, protractor not to scale.

06 Use a piece of masking tape to mark a starting line about a foot behind the bottom of the slope. Every test should start from the exact same place, with the front wheels on the starting line.

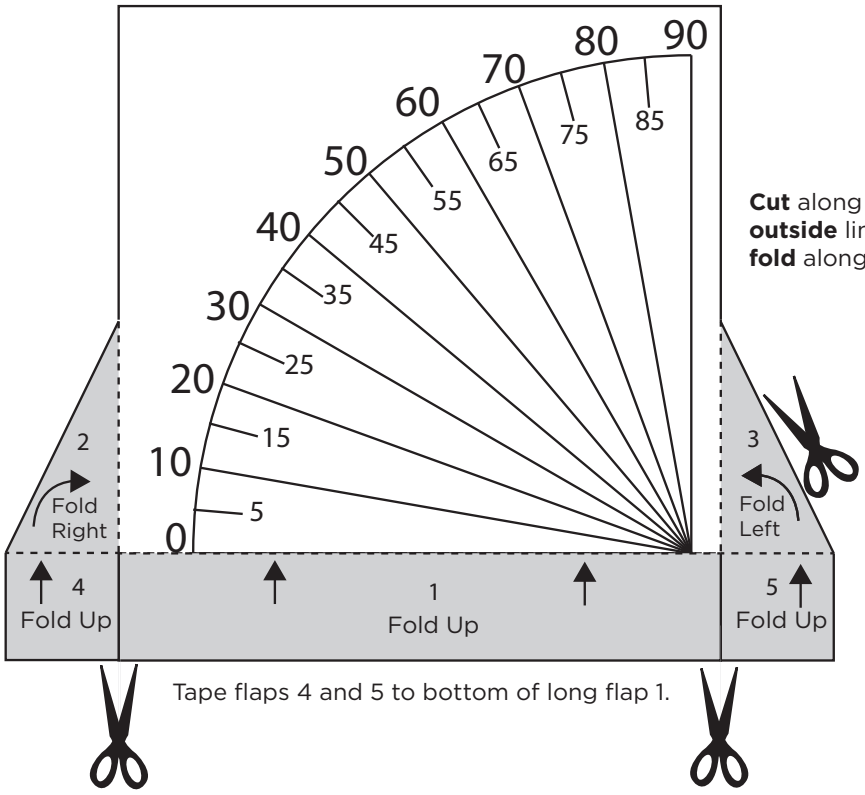
07. Review the instructions on the "Hill Climb" data sheet. Teams can begin testing climbing abilities by powering up either of the vehicles.

08 Each team should test each vehicle several times, adjusting the slope angle as indicated on the data sheet. Use the protractors to measure the angle of the slope. Have teams complete the data sheet to determine the maximum climbing angle for each vehicle.

Wrap It Up

- Ask teams to report on their results.
  - Was the maximum slope angle for the fire chief car and the motorcycle the same?
  - Which vehicle could climb the steepest slope angle?
  - Why do you think the motorcycle or fire chief car performed better on steeper slopes?
  - How did friction (from the different materials) affect how far the vehicles could climb?
- **Extension**
  - Is there a relationship between the power of the vehicle (hill-climbing ability) and its weight? Design an experiment that determines if there is a relationship and what that relationship is. (The fire chief car is the best vehicle to use because it is easy to add weight to it by taping a stack of metal washers or coins to its upper surface. Attempting to add weight to the motorcycle is likely to upset its balance.)
  - Try covering the cardboard hill with other materials (aluminum foil, plastic wrap, sand paper, parchment paper, etc.) to investigate the effects of friction on the climbing ability of the two vehicles. Rougher surfaces like sandpaper create more friction, which slows down the vehicle; smoother surfaces like plastic wrap reduce friction and might help the vehicle move more easily.

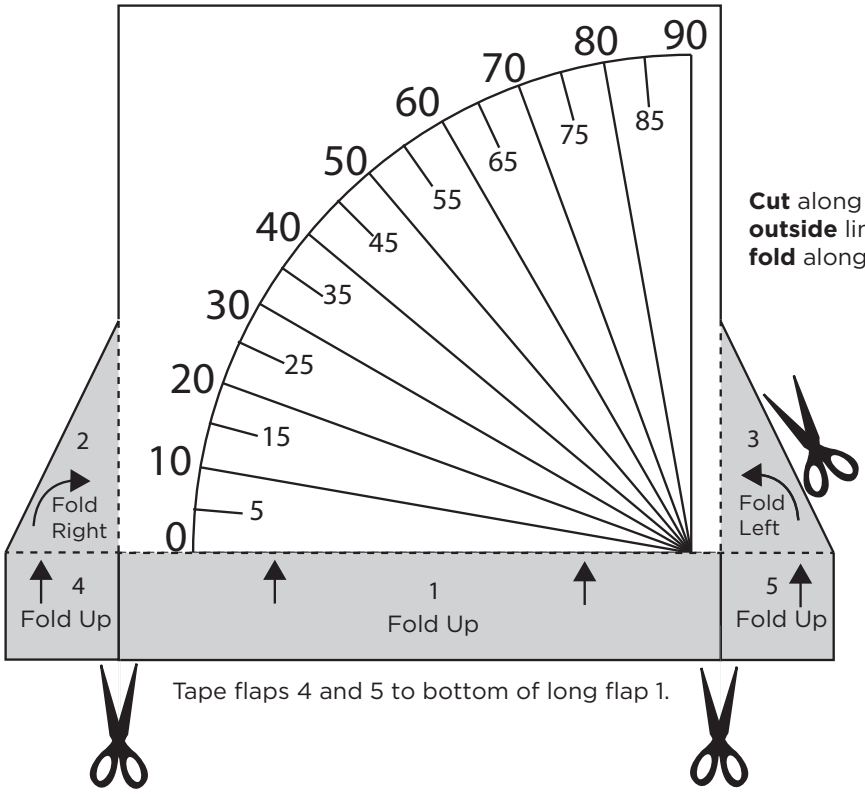
Protractor Pattern



Cut along the solid **outside** line and **fold** along the **dotted** line.

Tape flaps 4 and 5 to bottom of long flap 1.

Protractor Pattern



Cut along the solid **outside** line and **fold** along the **dotted** line.

Tape flaps 4 and 5 to bottom of long flap 1.

Hill-Climb Data Sheet

Team Member Names

_____ _____

_____ _____

Instructions

Construct a slope for your Hess fire chief car and motorcycle as described in the lesson. Use a protractor to measure the slope's angle.

- Start the tests on a low-angle slope.
- Test each vehicle's ability to climb the slope.
- Record the slope's angle and check the box when succesessful.
- After each success, increase the slope's angle and continue testing until each vehicle can no longer climb the slope.
- When all testing is completed, answer the concluding questions.

Fire Chief Car

Angle	Success

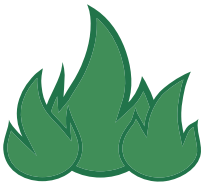
Motorcycle

Angle	Success

What is the maximum slope angle each vehicle could climb?

Which vehicle is better for climbing a slope?

Firefighters' Picnic



How do firefighters spend their leisure time when they're not fighting fires?

Suggested Grades **K–8**

7 Firefighters' Picnic

The Question

How do firefighters spend their leisure time when they're not fighting fires?

Where's the STEM?

Almost 70 percent of registered fire departments in the United States are volunteer fire departments (VFD). Many VDFs are in small towns and rural areas, and they are usually staffed by volunteer firefighters who go through rigorous training in the use of available equipment. Many VFDs have a collection of professional-level engines, tools, and safety equipment. Volunteer firefighters are not paid, but they share a great enthusiasm for protecting their communities. Funds to buy equipment and pay expenses come from grants by local, state, and federal sources. Other funds come from fundraising activities. One of the most popular fundraisers is the firefighters' picnic.

Organized by one or more nearby VFDs, these events invite the local community to attend and enjoy concessions and lively, exciting contests between the participating VFDs. A good example of one of these competitions is the barrel battle, a tradition that dates back to the 19th century. In a barrel battle, a wooden barrel is suspended from a wire stretched between two poles. Competing teams use their fire hoses to push the barrel back and forth until the barrel ends up at one of the poles or until the water runs out.

The force produced by the water streams is about 20 times greater than the force of a garden hose. According to Newton's third law of motion (for every action, there is an opposite and equal reaction), the force of the water stream creates an equal and opposite force on the firefighter holding and directing the stream. Therefore, it takes a lot of strength and skill to handle the fire hose in this competition. In the end, both teams are rewarded by being water soaked, and the winning team gets a trophy. In addition, the event actually serves as a crew-training activity on the use of fire hoses. It's a lot of work but also a lot of fun!

Because the Hess fire truck does not include a functioning fire hose, pump, or water tank, the barrel battle won't be attempted here. Instead, teams will compete in three events involving the performance of the fire chief car and the motorcycle. One event will be a head-to-head race between fire chief cars, another will test the jumping ability of the fire chief cars, and the third will be a wheelie obstacle-course challenge for the motorcycles. Each event is an opportunity to train fire crews in the effective use of essential firefighting equipment.

Materials

PER INVESTIGATION TEAM

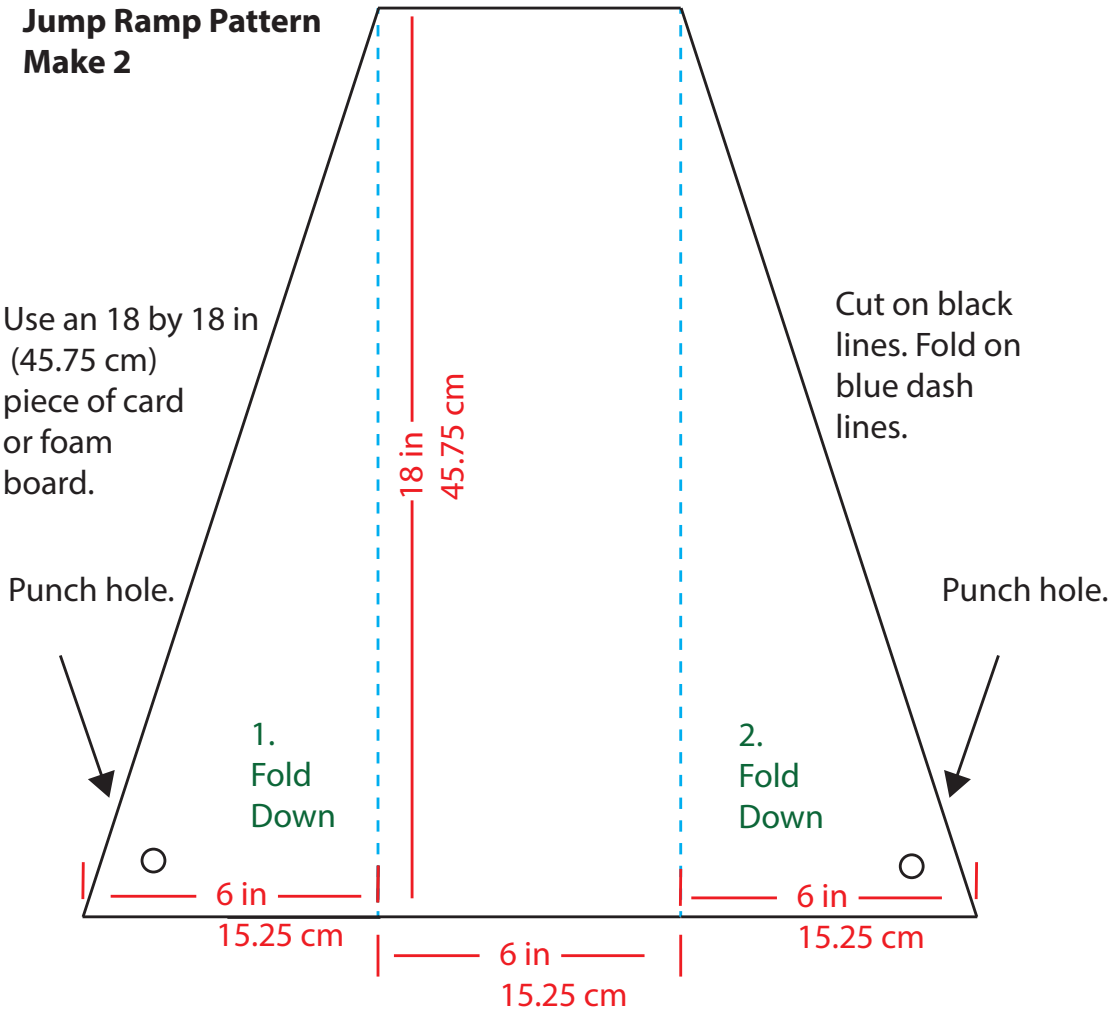
- 2024 Hess Fire Truck with Car and Motorcycle

FOR THE CLASS

- 20 feet (6.09 meters) of clear floor space (a hallway will work nicely)
- 2 jump ramps made from cardboard or foam board
- 6 books of equal size
- masking tape or painter's tape
- string
- hardware nail
- ballpoint pen
- straightedge ruler

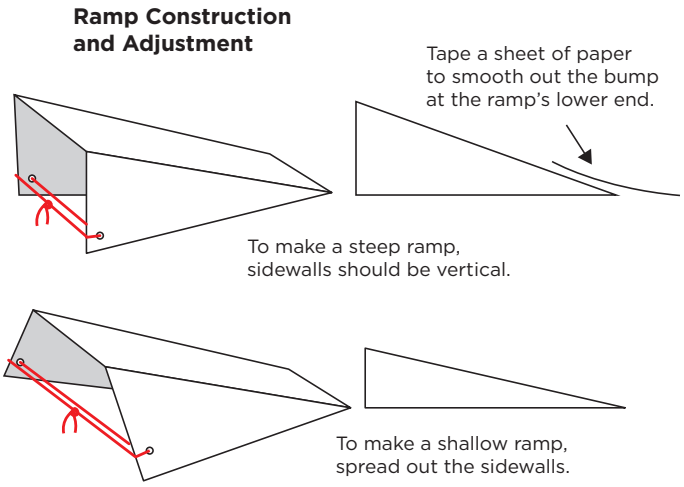
Management Tips

- Construct two jump ramps prior to the start of the competition. Use cardboard or foam board to build the ramps. (See instructions below. Younger students may need prebuilt ramps and a simpler layout for the obstacle course. The teacher or older students can assist in setting these up.) Old science fair display boards can also be used. String loops will support the sidewalls of the ramps. Change the length of the string loops to adjust the slope angle. Holes for the string can be made by using a hardware nail as a punch.



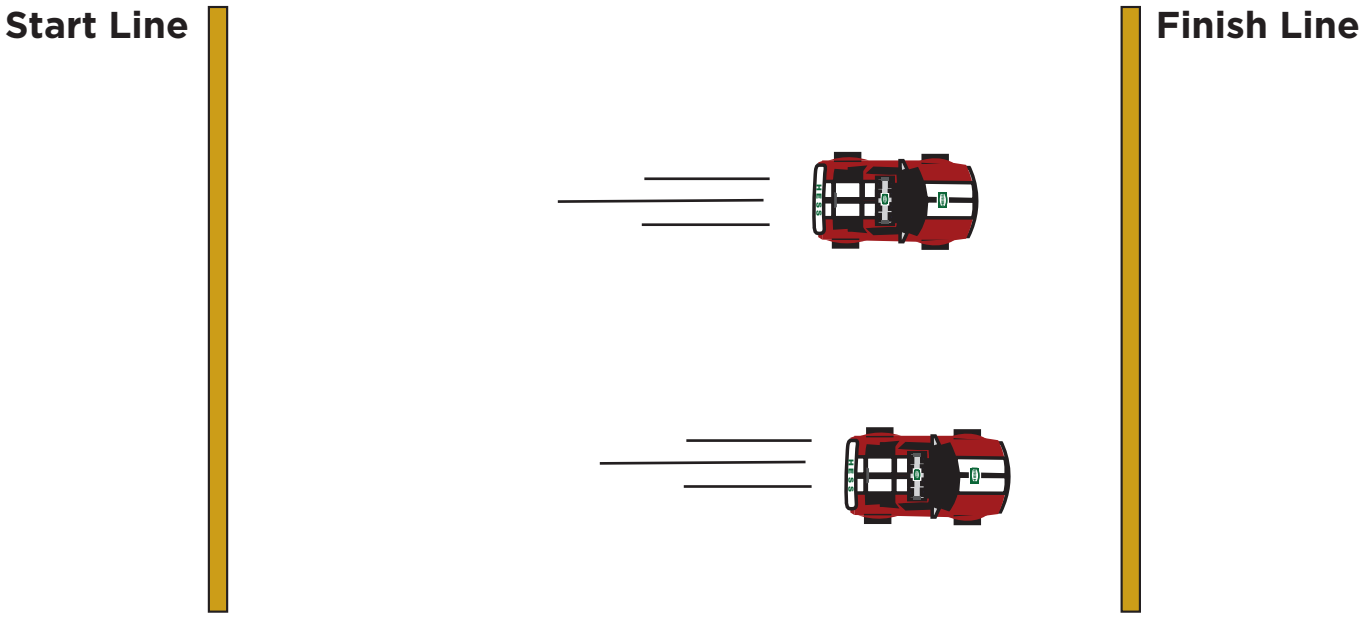
Management Tips Continued

- Lay out the three competition areas as shown in the illustrations below. A hallway can be used for the race between the fire chief cars. The other events each need about 10 feet (~3.04 meters) of clear space.
- Use masking tape or painter's tape to make the starting lines for each event.
- Place the books for the Wheelie Obstacle Course according to the diagram below.
- Remind drivers of the fire chief cars and the motorcycles to clean the wheels of the vehicles before beginning their events. Dust reduces the traction, speed, and the distance the vehicles can travel.



Fire Chief Car Race

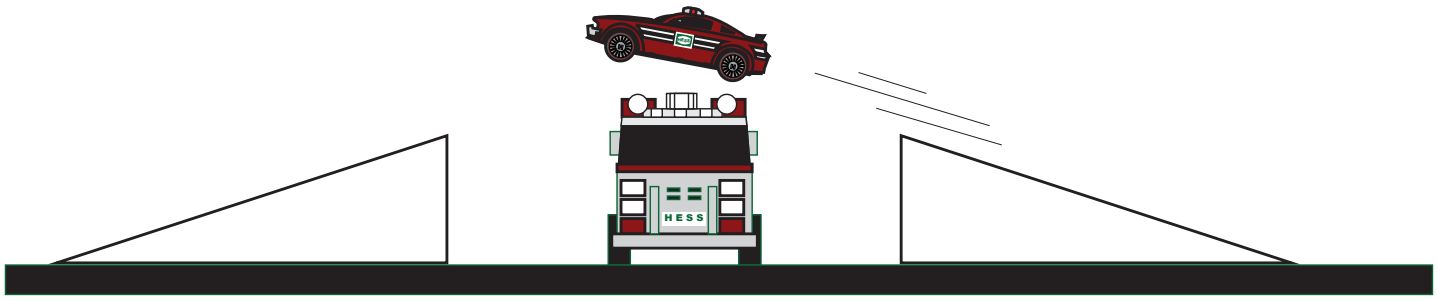
- Lay out the race course by placing a tape strip on the floor for the starting line and another tape strip about 15–20 feet (~4.5 –6.09 meter) away for the finish line.
- Have two competing teams conduct the race.
- Teams will select 1 driver (to wind up and release the vehicle), and 1 team member to do a countdown (3, 2, 1, GO!). Other team members will judge which car crosses the finish line first. Cell phone video recording can be used for photo finishes.
- Allow 3 attempts.



Management Tips Continued

Jump Competition

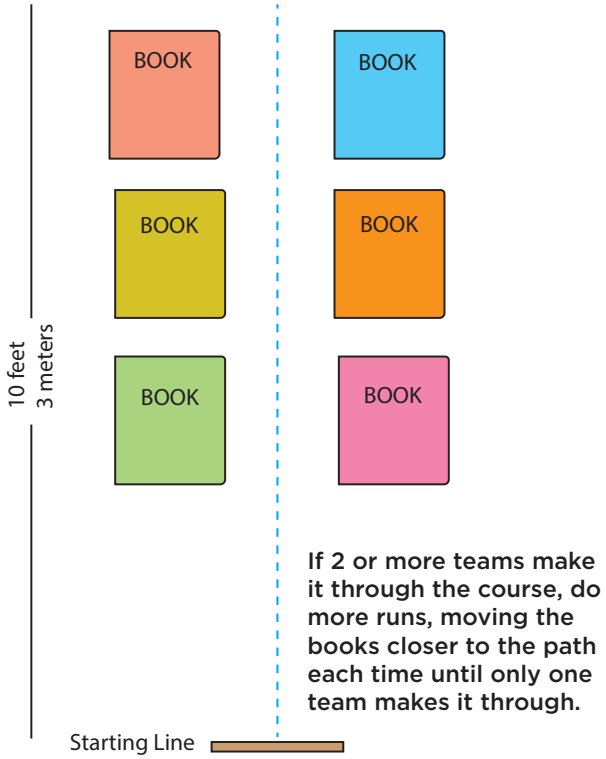
- Set up the jump course and use tape to mark the starting line.
- Place a fire truck between the two facing ramps.
- A driver will wind up and release the car on the count of 3.
- The idea is to clear the truck and land safely on the second ramp. Adjust the ramp angles to change the height of the jumps. Move the ramps closer together or further apart to adjust the length of the jump.
- Give each team 3 attempts.



Motorcycle Obstacle Course

- Lay out the books according to the plan below. Begin by placing the books 1 foot apart. Use tape to mark the starting line.
- Have teams practice driving straight through the course with both wheels on the ground, then they can practice doing wheelies.
- Conduct the competition with the motorcycles doing wheelies—the tail behind the motorcycle's rear wheel permits the motorcycle to stand on end as it races across the floor.
- Allow 3 attempts.
- If teams make it through the course successfully, do more runs, each time moving the books closer to the path until only one team makes it through.

Fire Motorcycle Course



Procedure

01 Explain the purpose of a firefighter's picnic. Besides fun for the firefighters and the community, such picnics are great fundraisers for volunteer fire departments. Competition between different VFDs hones firefighting skills and builds camaraderie.

02 Announce that the 3 competitions today will be a Fire Chief Car Race, a Jump Competition, and a Motorcycle Obstacle Course. Show the layouts and describe what actions each will involve.

03 Prior to the competitions, let the teams know they will be in charge of conducting the events and designating who will do what during the competition (driver, timer, etc.).

04 Tell them they will have 3 attempts at each competition.

05 Allow time for the teams to decide on individual roles.

06 Let the teams know that all the events will run simultaneously. It is at the teacher's discretion to decide how long each event should run before teams rotate to the next event.

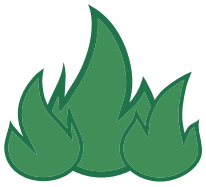
07 Given the competitive nature of this activity, there should be clear guidelines on how to avoid overlap in events or traffic jams in the hallway. For example, the teacher could designate areas for specific teams and assign judges or helpers to ensure that the races, jumps, and wheelie runs don't interfere with each other.

08 Point out that the car race will require 2 teams to compete against each other. (Students can also race together at the end of the competitions.) Remind the students that all cars should be released simultaneously to keep the competition fair.

Wrap It Up

- What did the teams learn about the performance of the vehicles in each challenge?
- What are the variables that affect the performance of the fire chief cars in the race? What factors contributed to their success, and what hindered their performance?
- What tricks can be used to ensure the motorcycle makes it through the obstacle course in the wheelie mode?
- What is the relationship between the angle of the jump ramps and the height and distance of the jumps?
- *What were the challenges of each event?* In all events, having clean wheels make a big difference. With dusty wheels, a vehicle loses traction on the smooth floor and may veer off course. In the race, drivers may not release their wound-up chief cars simultaneously. A slower release gives the other drivers a head start. Success in the obstacle course depends on careful aiming of the motorcycle and a smooth release that keeps the vehicle on course.
- What could you change about the design of the ramps or the course to make the challenge harder or easier?
- How would adding weight to the fire chief car affect its performance?
- Ask teams to invent their own events for a fireman's picnic using the Hess vehicles.

Custom-Designed Fire Truck



What kind of fire truck can you design, and what will its purpose be?

Suggested Grades **K–8**

8 Custom-Designed Fire Truck

The Question

What kind of fire truck can you design, and what will its purpose be?

Where's the STEM?

There are many types of fire trucks, each uniquely designed to fulfill specific tasks and operate effectively in diverse environments. Fire truck designs are informed by fire science, mathematics, engineering principles, and firefighting technology.

The most common type of fire truck is an engine truck, which carries water, hoses, and other firefighting equipment to the scene of a fire. Another common fire truck is a ladder truck, which is equipped with a large, extendable ladder used to reach high places. The 2024 Hess Fire Truck with Car and Motorcycle resembles a quint fire truck, which combines the features of an engine truck and ladder truck, making it a versatile firefighting tool.

Here is more information about some of the different kinds of fire trucks available for fire departments:

1. **Engine truck**: Often referred to as a fire engine, this is the most common type of fire truck. It carries ladders, hoses, and other firefighting equipment to the scene of a fire.

"Fire Engine 33" by Tony Hisgett is licensed under CC BY 2.0

2. **Ladder truck**: Equipped with a large, extendable ladder, this truck is used to reach high places, making it essential for urban environments with tall buildings.

"Akron Fire Department Ladder 7" by Seluryar is licensed under CC BY 2.0

3. **Rescue vehicle**: Also known as a technical rescue vehicle, it carries tools and equipment for complex rescue missions, such as extricating victims from car accidents or collapsed buildings.

"Lane Fire Authority Heavy Rescue Truck" by Only in Oregon is licensed under CC BY 2.0

Where's the STEM? Continued

4. **Brush truck**: Designed for wildfires, this truck can navigate rugged terrain and is equipped with an onboard pump to fight brush fires.

"Kansas City, KS FD Brush Truck 8" by KansasScanner is licensed under CC BY 2.0

5. **Tiller**: Also known as a tractor-drawn aerial, this truck of ladder truck has an extended reach and a steerable rear axle that helps it navigate tight streets.

"LAFD Truck 3 with tiller" by Jason Lawrence is licensed under CC BY 2.0

6. **Tanker/Tender**: This vehicle carries large volumes of water to areas that lack a sufficient water supply, such as rural or suburban regions. A tanker truck is accompanied by an engine truck with hoses, ladders and other equipment.

"Water Tanker Truck 20, US Air Force" is licensed under CC BY 2.0

7. **Command vehicle**: Often used by senior officers, this vehicle serves as a mobile command center for coordinating firefighting efforts at the scene.

"FDNY Battalion Chief 1 " by Peter Stehlik is licensed under CC BY 3.0

8. **Quint**: A quint (short for "quintuple," or five) combines the features of an engine and a ladder truck—with its water pump, water tank, fire hose, aerial device, and ground ladders, it serves multiple purposes.

"PBCFD Quint 57 Side View" by Joedamadman is licensed under CC BY 3.0

Where's the STEM? Continued

Each type of fire truck plays a vital role in the overall strategy of firefighting and rescue operations. Their design and onboard equipment enable firefighters to respond effectively to various emergencies, from urban-structure fires to wildland blazes to technical rescues. The Hess fire truck includes a fire chief's car and a motorcycle. Fire chief cars are commonly used by urban fire departments, and motorcycles may be used in rural areas for rapid responses to incidents such as small fires started by lightning strikes.

The different equipment fire trucks carry reflects the T and the E (Technology and Engineering) in STEM. In the world of education, STEAM expands on STEM by integrating the Arts, fostering creativity alongside science, technology, engineering, and math. The arts play a crucial role in design, problem solving, and innovation, allowing students to think more broadly and creatively when approaching engineering challenges. In this activity, students or teams will use their technical skills and artistic creativity to design custom fire trucks that are not only functional but also visually unique. They will also design an emblem or patch to wear on their clothes like firefighters do.

Materials

FOR THE CLASS

- craft paper or other large paper for drafting a truck design
- various construction materials, such as cardboard, posterboard, aluminum foil, plastic bottles, and egg cartons
- art supplies, such as markers, crayons, tape, glue, and paint
- tools, such as rulers, scissors, and paper punches
- "Fire Department Patches" page

Management Tips

- The first step in creating a custom-designed fire truck is to brainstorm what the purpose of the truck will be, what the truck should look like, and what firefighting tools it should have. If time does not allow for students to construct their own fire trucks, have students work in teams to make a detailed diagram of their truck for a bulletin board display.
- When all constructions or designs are ready, hold a gallery walk where teams explain the design and purpose of their trucks and answer questions from the other teams.
- For reference, go online to download pictures of different fire trucks to display on a smartboard, or print the images for a bulletin board. You can also download fire department patches to illustrate the diverse symbols used by different fire departments.
- For younger children, consider working on one model as a class, or enlist volunteers to work with student teams. Alternatively, younger children can draw or create posters of their custom-designed fire trucks rather than building physical models. Remind learners about the equipment found on different types of fire trucks and have them consider what equipment they will include in their designs.

Procedure

01 Show pictures of the 8 different types of trucks included in this lesson and explain what is special about each one. Let students share which truck is their favorite, and why.

02 Give students time to brainstorm ideas for their trucks. If students are working in teams, all team members should make sketches of their design ideas.

03 Have them consider how the truck's weight will affect its ability to carry equipment. What type of power source (engine, hybrid) will the truck use?

04 After students or teams have decided on their truck designs, have them begin construction of their custom fire truck model. Alternatively, students can create a poster of their designed truck and add labels to highlight the features of their truck.

05 Students should finish their project by creating an emblem patch representing their own fire department. They can use the suggested badge shapes on the "Fire Department Patches" student page below or come up with their own shape. Refer to notes on the page about emblem design.

Wrap It Up

- Conduct a gallery walk and have students or teams present their model or poster to the class and include answers to the following questions:
    - What kind of truck did you design?
    - How did the process of designing your truck make you think about what firefighters need during an emergency?
    - What challenges did you face while designing your truck, and how did you solve these challenges?
    - What type of equipment is on your truck (hose, ladder, water tank, etc.)?
    - What sort of equipment or supplies (water, foam, etc.) will your truck carry inside?
    - For what type of fire or in which kind of location could your firetruck be used?
    - What is the symbolism of your fire department emblem?

Extension Activity

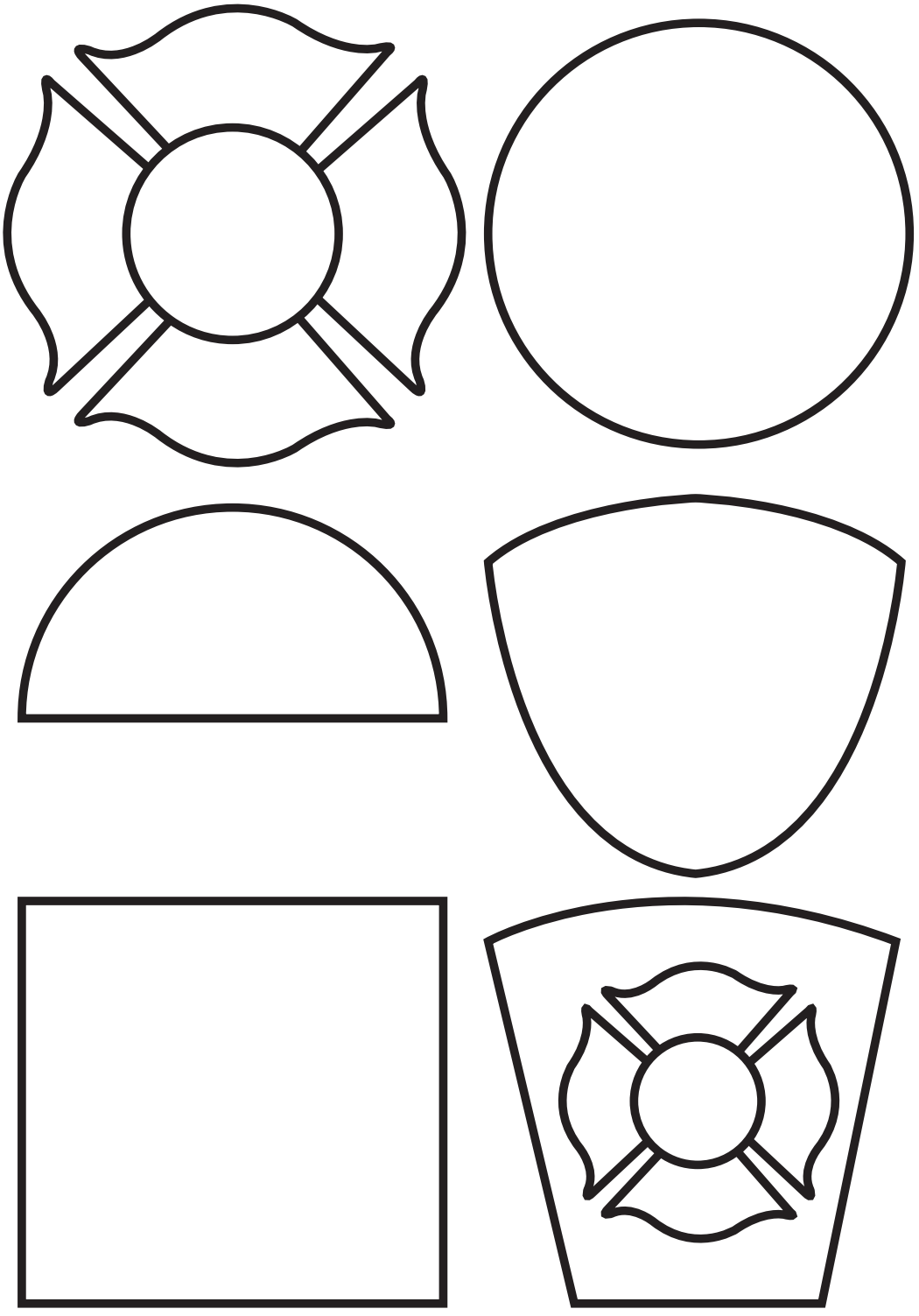
Have students measure the inside of the large compartment of the Hess fire truck. Use Lego bricks or some other small blocks to represent different pieces of firefighting equipment. Assume all pieces of equipment are the same size. How many bricks or blocks will fit in the compartment?

Have teams estimate the number and then try it. Remind teams that the equipment must be easily removed when needed. Do not jam bricks and blocks inside the compartment.

Fire Department Patches

Fire trucks are often adorned with distinct emblems that reflect the identity and pride of the fire department they serve. These emblems include symbols for firefighting equipment, things special about the community they serve, department history, and more. Often, emblems contain pictures of fire axes, ladders, hydrants, hoses and water, flames, fire hats, and even fiery dragons.

Pick one of these shapes for your patch, combine shapes, or come up with your own shape.



Glossary

Terms

combustion: a complex chemical reaction that occurs when a fuel reacts with oxygen.

emblem: as symbolic picture or badge that represents something important, such as a organization, nation, or family.

flywheel: a spinning wheel or disk, commonly attached to a rotating shaft, that stores kinetic energy.

force: a push or pull that makes things move or change direction; it includes

magnitude: (the strength of the push or pull) and direction.

friction: a force that happens when two surfaces rub against each other, resisting motion or movement.

fulcrum: the point where a lever pivots or balances.

gears: wheels with teeth that interlock with each other to transmit force and movement.

hydraulic system: a system that uses fluids to transmit force and movement.

hypotenuse: the longest side of a right triangle.

inertia: the property of matter that causes it to remain at rest or in motion unless acted upon by an external force.

kinetic energy: the energy of motion (as when a Hess Fire Truck races across the floor).

mass: the amount of matter that makes up an object.

MPH: the acronym for "miles per hour"; it refers to the number of miles a moving vehicle travels in one hour.

momentum: a measure of how much motion an object has; momentum equals the mass of a moving object multiplied by its velocity (e.g., a heavy truck is harder to stop than a light car traveling at the same velocity because the truck's momentum is greater).

Newton's first law of motion: Objects in motion stay in motion in a straight line, and objects at rest stay at rest unless acted upon by an external force; this law is also called the law of inertia.

Newton's third law of motion: for every action, there is an opposite and equal reaction.

oxidation: a process that occurs when atoms or groups of atoms lose electrons.

piston: a sliding piece that moves up and down inside a cylinder; this movement is essential in many mechanical systems, such as hydraulic systems that pressurize and move fluids.

potential energy: the stored energy an object has because of its position, interior stresses (e.g., wound spring, stretched rubber band), or electric charge.

STEM: an acronym for science, technology, engineering, and mathematics.

STEAM: an acronym for science, technology, engineering, arts, and mathematics.

volume: the amount of space an object or substance (solid, liquid, or gas) takes up.

weight: the force of gravity acting on an object; weight is usually measured in ounces and pounds.

Thank You!

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