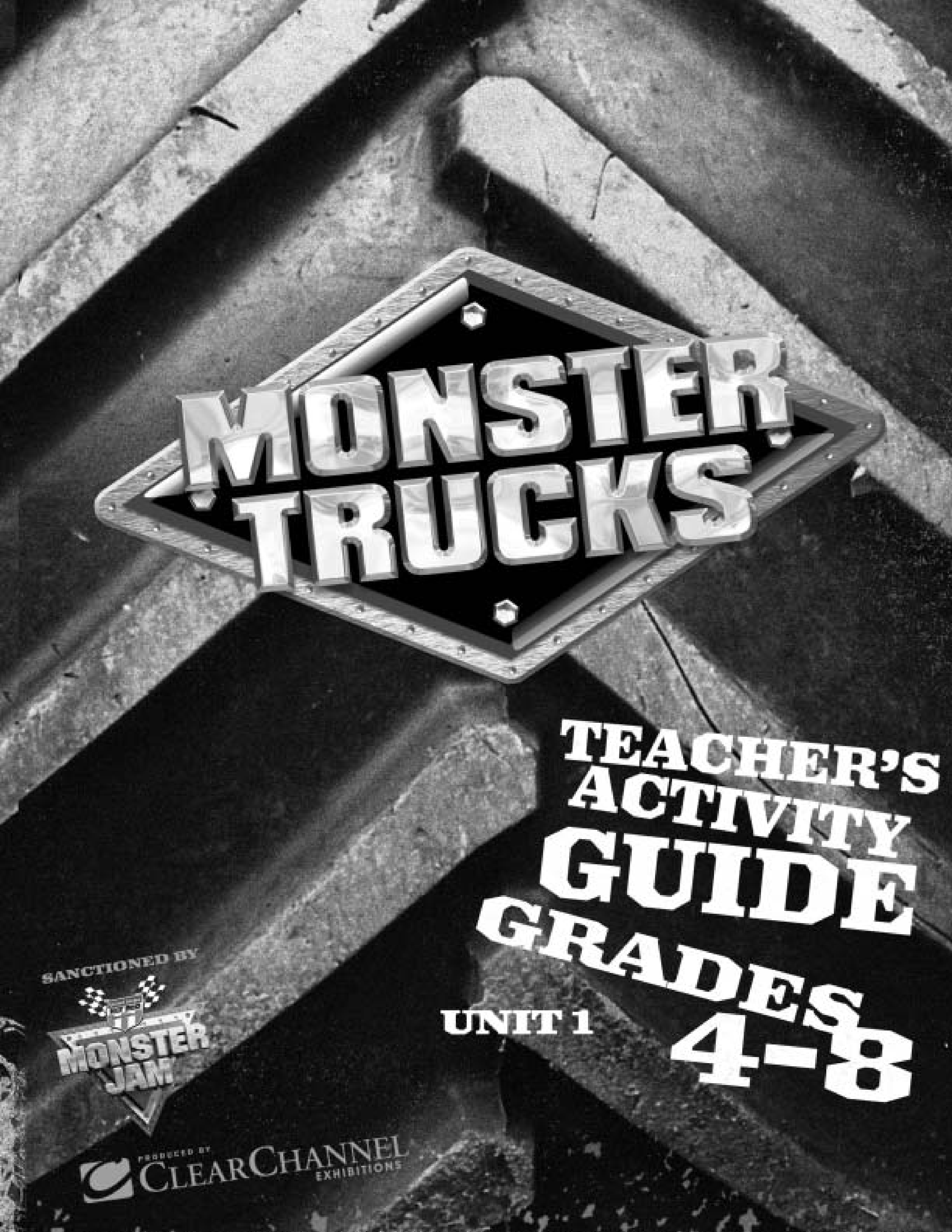

MONSTER TRUCKS

TEACHER'S ACTIVITY GUIDE

GRADES 4-8

UNIT 1

SANCTIONED BY

MONSTER JAM

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CLEAR CHANNEL EXHIBITIONS

Introduction

Welcome to *Monster Trucks: The Science of Extreme Machines*! As an educator, you have the Monster task of turning your students on to learning. We hope that this guide, in combination with the Monster Trucks traveling exhibit, helps fuel your students with a drive to learn.

The big beasts that are Monster Trucks exemplify many concepts and principles that are core components of math, physics, and auto technology classes. As a result, this guide provides a focus on three different units, so you can choose the lessons that best meet your classroom needs:

- Math and Science Lessons for Grades 4 – 8
- Physics Lessons for Grades 9 – 12
- Auto Technology Lessons for Grades 10 – 14

All of the lessons in this guide have been designed to complement the amazing *Monster Trucks: The Science of Extreme Machines* traveling exhibit. The lessons are standalone, using inquiry-based and hands-on approaches that enable students to recognize real-world applications of some of the skills and knowledge that are important to your classroom goals. Additionally, many of the lessons include reproducibles for you to use as handouts or on the overhead.

Units

Math and Science Lesson Plans for Grades 4 – 8

Covering a wide scope of student ages and abilities, this unit offers multiple tracks for you to take. Each lesson offers explicit suggestions on how to make it more or less challenging to better meet your students' needs. The unit is divided into a mathematics track and a physics track — each consisting of three separate lessons.

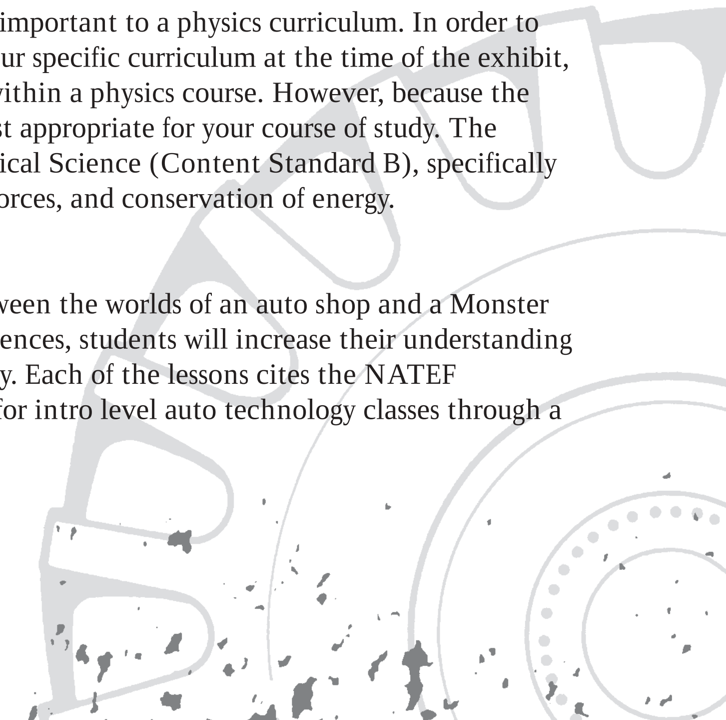
The math lessons emphasize skills that relate directly to National Council of Teachers of Mathematics standards including: Numbers and Operations, Algebra, Measurement, and Data Measurement and Probability.
The science lessons tie into the Physical Science standard (Content Standard B) of the National Science Education Standards, specifically the standard's emphasis on Motions and Forces, and on Transfer of Energy. They also tie into Content Standard E on Science and Technology.

Physics Lesson Plans for Grades 9 – 12

The lessons within this unit build off of many concepts that are important to a physics curriculum. In order to maximize the likelihood of having lessons that would tie into your specific curriculum at the time of the exhibit, the guide presents topics that are introduced at different times within a physics course. However, because the lessons are standalone, you can use them whenever they are most appropriate for your course of study. The lessons tie into the National Science Education Standards' Physical Science (Content Standard B), specifically to the standard's emphasis on chemical reactions, motions and forces, and conservation of energy.

Auto Technology Lesson Plans for Grades 10 – 12+

This unit takes advantage of the similarities and differences between the worlds of an auto shop and a Monster Truck shop. By better understanding those similarities and differences, students will increase their understanding of the two themes at the heart of this section: Engines and Safety. Each of the lessons cites the NATEF Standards for Certification that apply to it, and are appropriate for intro level auto technology classes through a post- high school level program.



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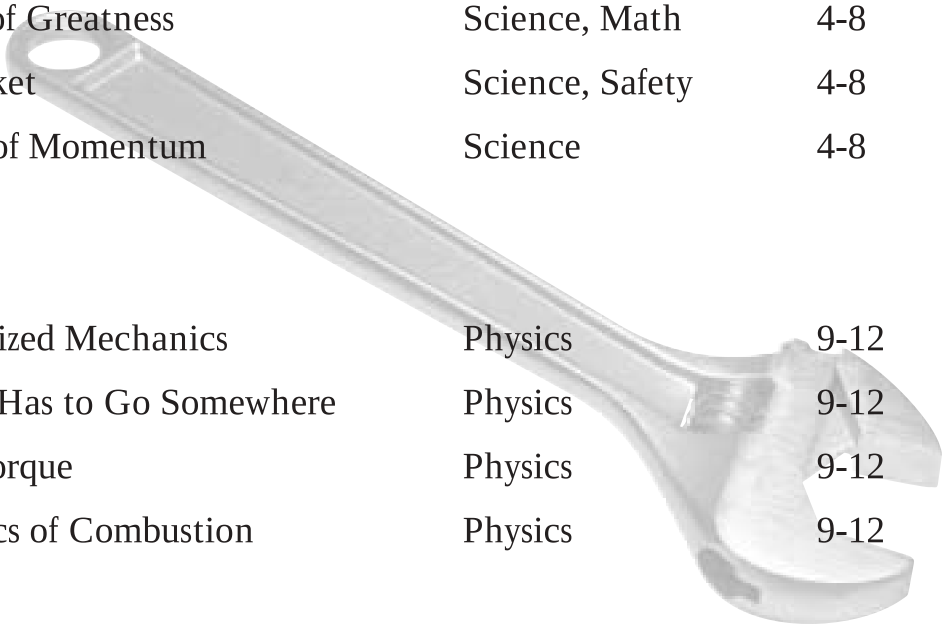


REINVENTING THE WHEEL

Objective:

Students will measure, calculate, organize, and present diameters and circumferences to predict which household objects will roll the farthest.

Curriculum Connection:

This lesson is an excellent way to introduce less advanced/younger students to circumference and reinforce measurement and calculation skills. Prior knowledge of the concept of diameter is necessary. By calculating the circumferences of a variety of cans, lids, and/or other round household objects, students will predict which objects will roll the farthest when traveling at the same speeds. They will then test their predictions by rolling the objects on a single, uniform surface. Students should conclude that vehicles with wheels of greater circumferences—such as Monster Trucks—travel greater distances than vehicles with wheels of lesser circumferences when speeds are equal.

Important Terms:

circumference, diameter, pi, radius

Exhibit Link:

This lesson is designed as a pre-exhibit activity that will prepare students for the sight and significance of the giant terra tires that define Monster Trucks.

Class Time:

45 minutes

Materials Needed:

- pencils
- rulers
- black felt-tip markers
- large ramp (optional)
- notebook paper
- tape measures
- calculators (optional)
- reproducible
- circular objects (such as different sized cans)
- stop watch (optional)

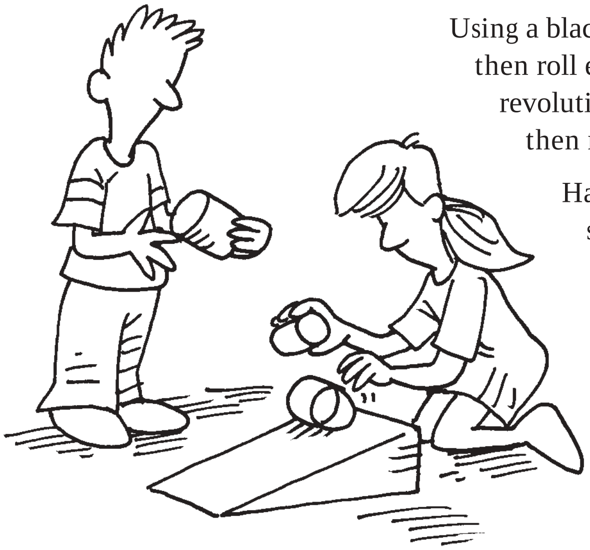
Lesson Steps:

1. **Using the reproducible, read about and discuss the Monster Truck tires.** Using rulers, students should measure the diameter of the Monster Truck tire illustration. Write either the exact or approximate diameter on the board, depending upon your students' calculation skills.
2. **Define circumference and pi, either as an introduction to or review of the terms.** Ask students to multiply the illustration's diameter by pi (either 3.14 or 3, depending on your students' abilities). Inform students that their product is the illustration's circumference. Additionally, students can figure out circumference if they know only the radius: $C=2\cdot pi\cdot r$.
3. **Introduce the circular objects with which students will be working** (either individually or in small or whole-class groups). Ask them to predict which object or objects will have the greatest circumference.
4. **Using tape measures, students should measure the diameter of each object.** Students should measure each object at least twice to make sure their measurements are accurate. Students should record diameters on notebook paper.
5. **Using calculators or pencils and paper, students should multiply each recorded diameter by pi and record the product as its circumference.**
6. **Students should organize and present their data in a table either independently, in small groups, or as a class** (depending on students' data presentation skills and whether all students are working with the same or identical objects). The table should include the following subtitles or fields:

Object Diameter Radius Circumference

7. **Using the table, students should predict which object will roll the farthest** (again, assuming speeds are equal) and, therefore, will make the best Monster Truck wheel.

8. **To conclude the activity, allow students to test their predictions by rolling some or all of the objects they have measured on a single, uniform surface.** The ideal surface is something like a ramp with a slight (10%) incline, so that students do not need to worry about rolling the objects at constant speeds. If a ramp is unavailable, a flat surface such as a classroom floor or basketball court is fine. Students, for example, could start with two tin or aluminum cans—one 16 ounces, the other 8 ounces.



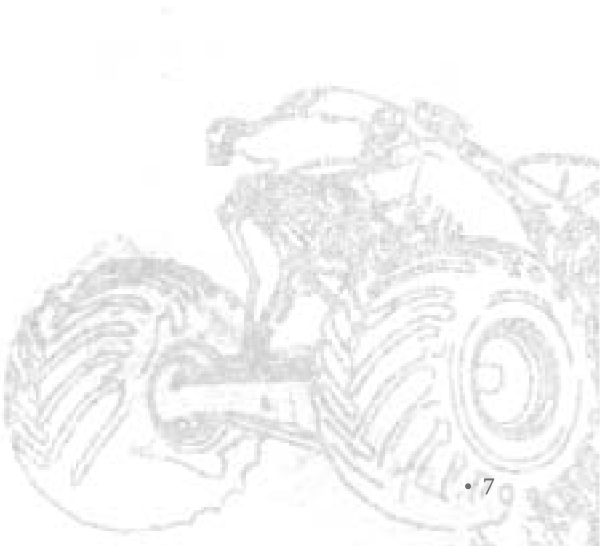
Using a black felt-tip marker, have a student make a visible mark on each can, then roll each can down the ramp. Students should count at least 10 revolutions (marking where the can finished its 10th revolution) and then measure the distance it traveled during those 10 revolutions.

Have students repeat the process using the other can. Make sure that students start with the marks in similar positions, e.g., straight up. To decrease the likelihood of errors, have students repeat the process at least once. Students should see that the object with the greatest circumference has rolled the farthest after 10 revolutions. If students are unable to roll their objects down a ramp, discuss ways that they can roll the objects with constant speeds. For example, the same person should do the rolling, and the follow through on the roll should be uniform.

Academic Extensions/Modifications:

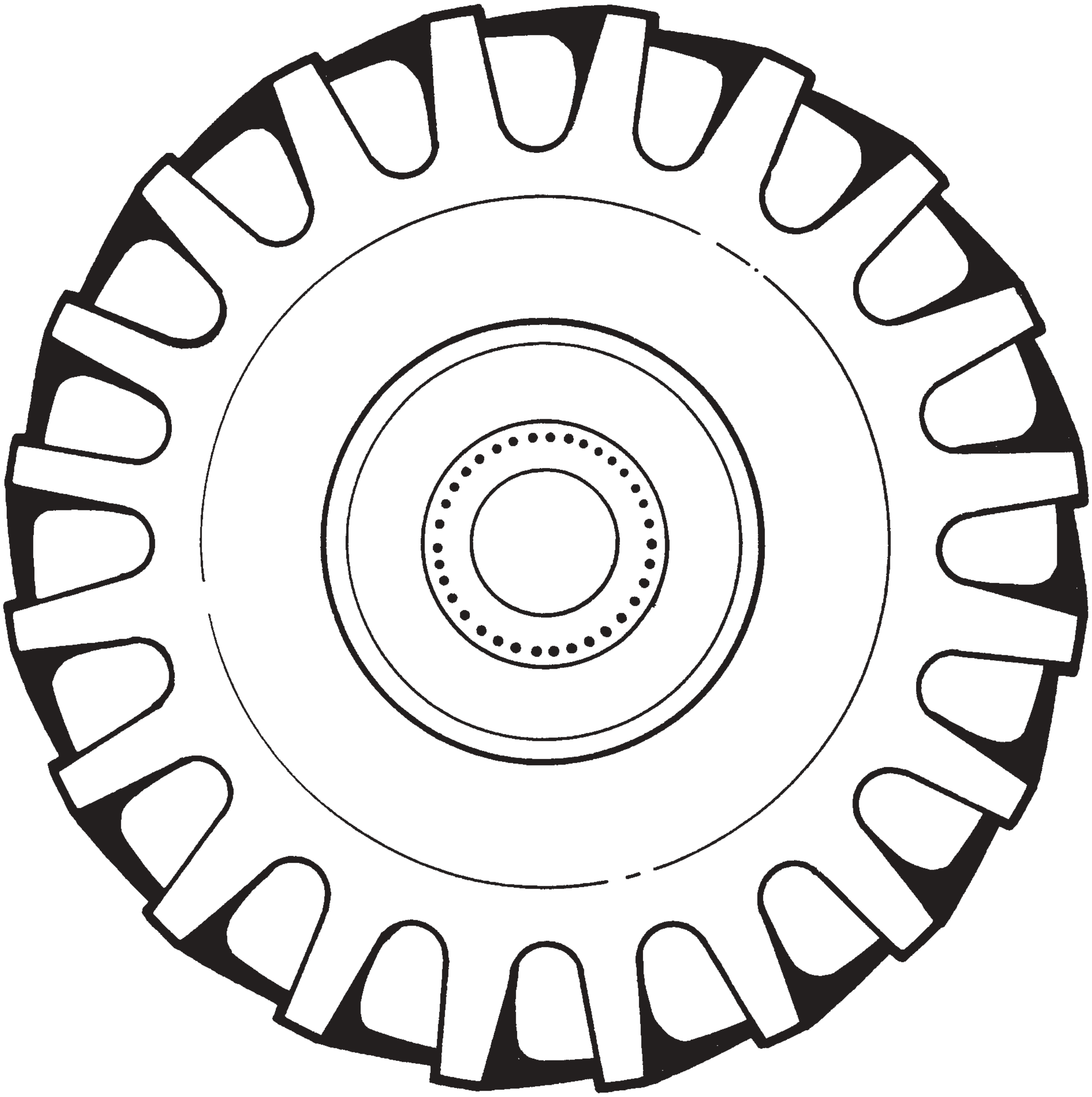
ELEMENTARY AND MIDDLE SCHOOL:

- To extend **Step 5**, have students use tape measures to measure each object’s circumference and compare these measured circumferences to the calculated circumferences.
- To extend **Step 6**, have students include a field in the table in which students enter the quotient of each object’s circumference divided by its diameter. It should always equal about 3 (or pi).
- To extend **Step 8**, students in upper level classes can collect data to plot distance versus time graphs either manually on graph paper or on graphing calculators. The slope of the distance versus time graph is the speed of the object.



MONSTER TIRES!

Monster Truck tires offer heavy-duty support. Each tire measures 5 1/2 feet across, and a rough-and-tough vehicle such as Grave Digger needs every inch (all 66 of them) to keep on truckin' across a track's treacherous obstacles. Each massive Truck tire weighs in at over 800 pounds. This tire, called a *terra tire*, has deep treads that help the truck get a good grip, or *gription*, on the track's dirt surface.



DATA DRIVEN

Objective:

Students will use variations of the formula speed = distance/time (s=d/t) to calculate, organize, and present data gathered from a hypothetical Monster Truck race.

Curriculum Connection:

This lesson gives students an excellent opportunity to use and develop their mathematical problem-solving skills as they describe and measure Monster Truck performance. Although no prior knowledge of speed as a scientific property is necessary, experience with making/using tables, dividing whole numbers by decimals, and solving multi-step problems is essential.

Class Time:

45-90 minutes

Materials Needed:

- pencils
- scratch paper
- reproducible
- calculators

Important Terms:

constant, distance, rate, speed, time, variable

Exhibit Link:

This lesson is designed as a post-exhibit activity that will allow students to connect their math skills to the Monster Truck driving simulation and students' sense of what it is like to roar toward the finish line.

Lesson Steps:

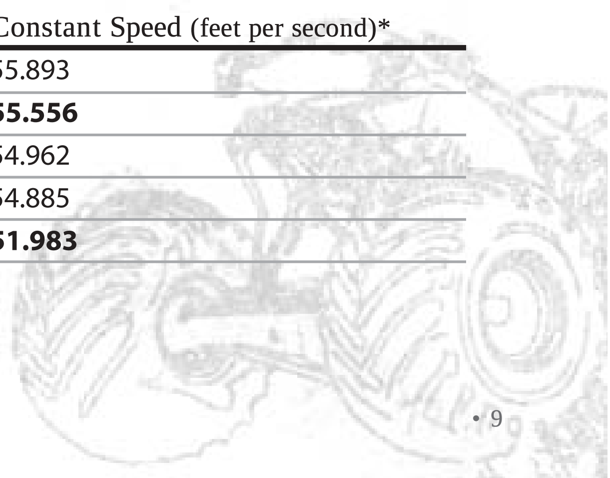
1. **Write the letters MPH on the board.** Many students will recognize this means "miles per hour." Ask students where they see "miles per hour" outside the classroom and ask them for numbers of miles per hour with which they are familiar (such as 35, 55, and 65).
2. **Using the number that seems most familiar to your students—e.g., 55—ask them what "55 miles per hour" means.** Many will correctly say it means how fast you're going; more/advanced older students will more specifically identify 55 miles per hour as a rate of speed. In any event, conclude this step with the fact that "miles per hour" is speed, and that speed is calculated using two measurements: distance and time.
3. **Write s=d/t on the board.** Refer to **Step 2** and ask students what "s" stands for (speed).
4. **Write the letters FPS on the board and ask students, if necessary, to compare this abbreviation with MPH to conclude FPS=feet per second.** Ask students which of these two units of speed would be more appropriate for finding the time it takes to travel short distances, such as a walk from one end of your classroom to the other. Note: If your students are accustomed to using metric units, change the abbreviation to reflect the unit of measure of choice.
5. Introduce the student copy of the table below:

350-Feet Straight Track Race

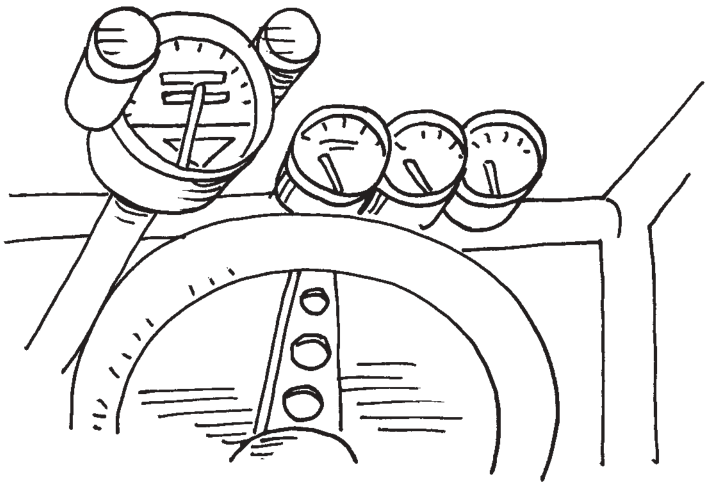
Monster Truck	Place	Finish Time (seconds)+	Constant Speed (feet per second)*
Grave Digger	1	**6.262**	55.893
Bulldozer	2	6.300	**55.556**
Monster Mutt	3	**6.368**	54.962
High Roller	4	6.377	54.885
Maximum Destruction	5	**6.733**	**51.983**

*rounded to the nearest thousandth

+ times are fictitious



The table represents data from a hypothetical Monster Truck race on a 350-ft. long straight-line track. Data missing from the students' copy is in **bold**.



6. **Guide students as necessary in a skim reading of the table.** Students should note after this reading that the speed from the race is in feet per second. Briefly discuss why the trucks' speeds are not in miles per hour—the units most often associated with automobiles. Use s=d/t to identify 350 feet as "d", a distance appropriate for walking, but a distance a Monster Truck would travel in seconds—much faster than the students or any human could travel on foot.
7. **Allow students to solve the problems on the student reproducible and to complete the table.** Guide their work as necessary. Problems are sequenced in order of increasing difficulty. Answers are as follows: 1) 6.262 seconds 2) 55.556 ft per sec. 3) 6.368 sec 4) a = 6.733 sec; b = 51.983 ft per sec 5) range=0.471 seconds, which illustrates that there is less than a half-second difference between a first-place finish and a last-place finish; mean finish time=6.408 seconds; mean constant speed=54.656 ft. per sec. *Please note that using the mean finish time as a way to figure out the mean constant speed will calculate to the answer: 54.619 ft. per sec — the discrepancy resulting from rounding.* 6) 111.786 ft/sec
8. **Conclude the lesson by checking the problems as a class and completing an overhead copy of the table.** Use the range of the times to discuss how a little time—in this case, less than half a second—makes a lot of difference between a first-place or a "worst-place" finish.

Academic Extensions/Modifications:

ELEMENTARY:

- Discuss with students the inverse relationship between time and place at the finish line: the less time it takes to finish, the greater your place. This concept, despite students' playground experiences, sometimes seems counterintuitive to less experienced/younger students in a classroom context.

MIDDLE SCHOOL:

- Provide more advanced students with a table minus all data and the data out of order of finish on the board or overhead.
- Use the table column at right as an extension of the table with which your students have been working.

  Instruct students to create a column for the ETA @ Mile Marker, and ask them how long it would take each truck to travel a mile, assuming speed is constant. Students must divide the number of feet in 1 mile (5,280) by the feet per second each truck is traveling. Students also can change the seconds into minutes and seconds by rounding each decimal to the nearest second and dividing it by 60 seconds using pencils and paper. These conversions also can be made by more advanced students mentally. This extension will again illustrate for students how close these times are—Monster Mutt's and High Roller's times, for example, are identical when rounded to the nearest second—and why speed during a race is measured to thousandths of a second.

ETA @ Mile Marker (seconds)
94.466 (1m 34s)
95.039 (1m 35s)
96.066 (1m 36s)
96.201 (1m 36s)
101.572 (1m 42s)

Mean Speeds

Use the table to solve the problems below.

350-Feet Straight Track Race

Monster Truck	Place	Finish Time (seconds)	Constant Speed (feet per second)*
Grave Digger	1		55.893
Bulldozer	2	6.300	
Monster Mutt	3		54.962
High Roller	4	6.377	54.885
Maximum Destruction	5		

*rounded to the nearest thousandth

1. On a 350-ft. straight-line track, Grave Digger crosses the finish line .038 seconds before Bulldozer. If Bulldozer finished the race in 6.300 seconds, how many seconds did it take Grave Digger to win the race? Enter the data into the table.

2. Bulldozer finished the race in 6.300 seconds. Assuming Bulldozer's speed was constant, what was the truck's rate of speed? Enter the data into the table.

3. Given Monster Mutt's constant speed on the track, how many seconds did it take the truck to cross the finish line? Enter the data into the table.

4. Not a good night for Maximum Destruction! This Monster Truck's performance was monstrously unsatisfactory—Destruction crossed the finish line almost 4/10 of a second (0.356 seconds, to be exact) after High Roller. That's not so slow, you say? Well, look at your completed table after you a) find Destruction's finish time, b) find Destruction's constant speed, and c) enter the data into the table.

5. Now that you've eyeballed all the trucks' finish times and rates of speed, why do you suppose every thousandth of a second can matter in these short-distance races? Calculate the range of finish times and see what a difference a decimal can make. Also crunch your numbers to find the mean finish time and mean rate of speed.

6. Here's a MONSTER challenge! In an actual race, the Monster Trucks would start from a standstill position and the initial speed would be zero. The constant speed you used to calculate times in your table is really a "mean speed," also called "average speed." If the average speed is defined as (initial speed + final speed) / 2, what is the final speed for Grave Digger?

FUEL FOR THOUGHT

Objective:

Students will calculate amounts of fuel consumed or stored using fractions and decimals.

Curriculum Connection:

This lesson is an excellent way for students to work with fractions and decimals as representations of the real-world energy source that moves Monster Trucks—and almost all of our automotive vehicles—every day: fuel. Students should be able to multiply fractions and whole numbers and divide decimals.

Class Time:

45 minutes

Important Terms:

capacity, consume, customary, dashboard, gauge, metric

Exhibit Link:

This lesson is designed as a post-exhibit activity that will allow visitors to get a sense of how Monster Trucks and all automotive vehicles consume fuel.

Materials Needed:

- pencils
- calculators (optional)
- scratch paper
- problem-solving reproducible
- fuel gauge reproducible

Lesson Steps:

1. **As a class, discuss with students how one knows when it's time to "fill it up," or refill an automobile's fuel tank.** Students believing that they are pointing out the obvious might say, "When it's empty"; you should point out that that's too late. Sustain answers such as "almost empty" but ask students how much "almost empty" is. Point out, if necessary, that there's something on an automobile's dashboard that shows how much gas is "in the tank"—the fuel gauge.
2. **Introduce the fuel gauge reproducible.** Ask students what the markings represent and guide students as necessary to label the markings with the appropriate fractions. (For example, you could ask less advanced/younger students what the middle mark represents if the far right mark means "full.") Tell them they should use a finger or pencil to represent the fuel gauge's needle.
3. **Using the fuel gauge, ask students again about when it's time to refuel.** If, for example, students say it's when the needle drops below the 1/4 mark, ask them how much fuel they will need to fill up (1/4 full=3/4 empty). Guide this process as necessary, and ask how much fuel they'll need when the tank is 1/2 and 3/4 full.
4. **If students have not already discussed these amounts as gallons, introduce the term.** In any event, you likely will need to remind students that a) gallons are units of capacity; and b) capacity is a measure of how much a container, such as a fuel tank, can hold.
5. **Ask students whether they know how many gallons of fuel an automobile can hold.** This is an excellent opportunity to further engage students' prior knowledge and inference skills. Students might recall how many gallons of gas it takes to fill up the family automobile and conclude through discussion and/or prior observation that different vehicles have different fuel capacities. Guide students to this conclusion as necessary.
6. **Introduce to students the fuel capacities of three familiar vehicles:** the five-seat Toyota Tercel (11.9 gallons); a Ford Sport Utility Vehicle, the Explorer (22.5 gallons); and Grave Digger (20 gallons).
7. **Ask students to estimate how much fuel each vehicle contains when it's 1/2 full.** Either independently or as part of guided practice, students should multiply each of the three fuel capacities above by 1/2 to determine the number of gallons of fuel in a 1/2 full tank, which students should infer will also be the

number of gallons that have been consumed (Tercel=5.95 gallons; Explorer=11.25 gallons; Grave Digger=10 gallons).

8. For each of the vehicles, ask students to find the number of gallons of fuel 1/4 full and 3/4 full represents. The answers are below, along with the number of gallons each vehicle contains when it is 1/4 empty and 3/4 empty:

Vehicle	Total Fuel Capacity	1/4 full	3/4 empty	3/4 full	1/4 empty
Toyota Tercel	11.9 gal.	2.975 gal.	2.975 gal.	8.925 gal.	8.925 gal.
Ford Explorer	22.5 gal.	5.625 gal.	5.625 gal.	16.875 gal.	16.875 gal.
Grave Digger	20 gal.	5 gal.	5 gal.	15 gal.	15 gal.

9. Conclude the lesson by introducing the problem-solving reproducible to be completed in class or as homework. Students will need their answers to Step 7 to complete the problems. Problems are sequenced in order of increasing difficulty. Answers are as follows: 1) 20 miles; 2) 2.5 or 2 1/2 gallons; 3) 12.5 or 12 1/2 full, 7.5 or 7 1/2 gallons empty; 4) 16 gallons, 4 gallons; 5) #2 = 9.48 liters, #3 = 47.36 liters full and 28.43 liters empty, #4 = 60.64 liters and 15.16 liters.

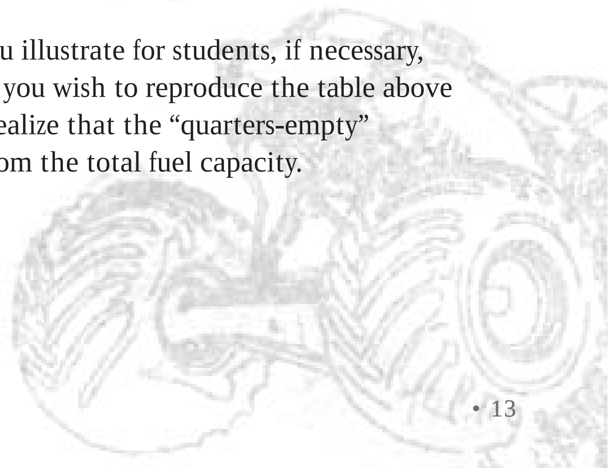
Academic Extensions/Modifications:

ELEMENTARY:

- For less advanced/younger students, Step 5 is an excellent opportunity to reinforce the concept that proportionality is relative, and that the value of a fraction of a whole number changes, or varies, when the whole number's value changes, or is variable. For example, you can guide students to the discovery that 1/2 the fuel capacity of the Explorer is about the same as the fuel capacity of the Tercel, which stands to reason because the Explorer's total fuel capacity is about twice the Tercel's total fuel capacity.
- Cut out and laminate a photocopy of the fuel gauge, station it with dry erase markers, and allow students during free time to correctly match fractions to their locations on the gauge; then, calculate the fraction of fuel stored or consumed based on a randomly drawn number indicating the capacity of the fuel tank.

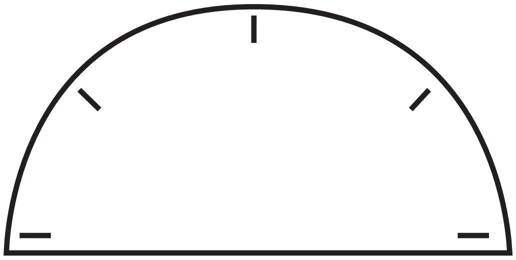
MIDDLE SCHOOL:

- In Step 7, more advanced/older students likely will see that they can save a step by dividing the fuel capacities by 2, instead of first multiplying by 1/2; ask them whether the multiplication step can be skipped when the numerator is greater than 1, as in 3/4. As they will see in subsequent problems, multiplication sometimes will be necessary.
- The table in Step 8 includes the "quarters-empty" amounts to help you illustrate for students, if necessary, that there is more than one way to solve these problems. In the event you wish to reproduce the table above (either with or without the answers), you can use it to help students realize that the "quarters-empty" amount can be calculated by subtracting the "quarters-full" amount from the total fuel capacity.



FUEL FOR THOUGHT

Solve each problem. Read carefully. All fractions should be represented in simplest form.



1. Assume that for every gallon of fuel that Grave Digger consumes, the truck can run for 2 miles. If Grave Digger's 20-gallon tank is 1/2 full, how many miles can Grave Digger go before needing to be refueled?

2. Only 1/2 of Grave Digger's 20-gallon fuel tank remains full. Unfortunately, 1/4 of that remaining fuel has leaked. How much fuel has leaked from Grave Digger's tank? Write your answer as a decimal and a fraction.

3. After a busy day, 5/8 of Grave Digger's 20-gallon tank remains full. How many gallons of fuel are left in the tank? How many gallons have been consumed? Write your answers as decimals and fractions.

4. Grave Digger's 20-gallon fuel tank is 80% full. How many gallons of fuel are in the tank? How many more gallons can be filled?

5. Look back at your answers for problems 2-4. If 1 gallon = 3.79 liters, how many liters do each of your answers equal? Round your answers to two decimal places.

6. Be the teacher! Create a problem of your own using concepts from this lesson. State the problem clearly and challenge a classmate to solve your problem. If your classmate cannot solve the problem, explain the problem to your classmate. Share your problem with your teacher and explain how you decided on the type of problem to create.

MEASURES OF GREATNESS

Objective:

Students will use the concepts related to kinematics to measure and calculate the time, distance, speed, and acceleration of toy cars. Advanced students will graph distance versus time to determine speed, and speed versus time to determine acceleration.

Important Terms: *acceleration, distance, kinematics, speed, velocity*

Exhibit Link:

This lesson serves an excellent pre-exhibit activity. Monster Trucks require incredible power to accelerate and move through obstacle courses at amazing speeds. It will be helpful for students to understand how the concepts of speed, distance, and acceleration relate to trucks prior to seeing them in action. When students visit the Safety Seats area of the exhibit, they can then experience a sense of acceleration, deceleration, and going up/down an incline.

Curriculum Connection:

The beginning of physics is rooted in describing motion (kinematics). To describe motion, we begin by measuring distance and time. From distance and time measurements, we can calculate speed and acceleration. Speed can be calculated by dividing the distance traveled by the time ($s = d/t$). If the speed is measured at two different times (e.g., 15 ft/s and then 20 ft/s two seconds later), the acceleration can be computed by dividing the difference in speeds (20 ft/s - 15 ft/s) by the time between the measurements ($5 \text{ ft/s}/2\text{s} = 2.5 \text{ ft/sec}^2$). For the purposes of this lesson, linear motion is used (with no changes in direction); therefore speed = velocity, and distance = displacement.

Class Time:

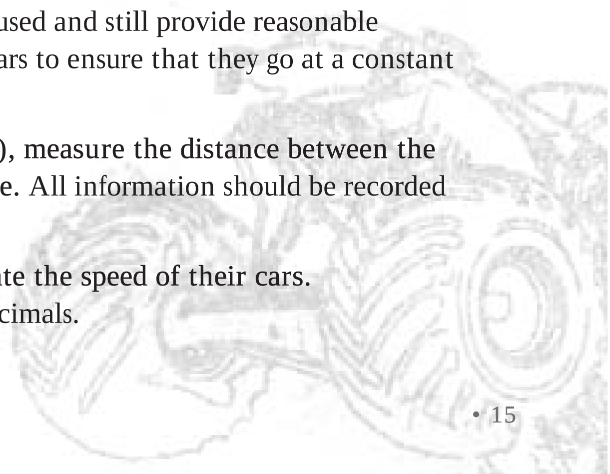
One 50-minute class period is required to measure the speed, and one 50-minute class period is required to measure the acceleration. Additional time may be required to produce the graphs.

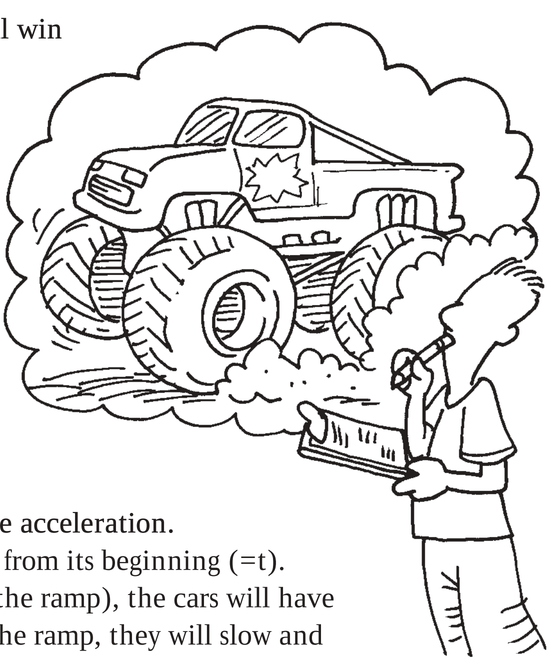
Materials Needed:

- graph paper
- stopwatches (or watch with a second hand)
- measuring tools: rulers, meter sticks, yard sticks or tape measure
- pencils, pens
- incline planes (wide, long boards)
- wind-up cars (or battery operated cars)

Lesson Steps:

1. **As a class, spend 10 minutes introducing or reviewing the terms above related to kinematics.** Modify the level of detail of the concepts based on your classroom skill level. An important point to consider for this lesson is that for linear motion, speed and velocity are interchangeable. If the lesson involved a change in the direction of the cars, then the more complicated concepts of velocity as a vector and displacement would need to be introduced. These concepts are generally too advanced for grades 4-8.
2. **Provide pairs of students with electric/wind-up cars (that travel at a constant speed), rulers, and clocks.** If stopwatches are not available, the activity can be completed in a gym that permits extension of the distance (and time) so that a clock with a second hand sweep can be used and still provide reasonable measurements. Note: Before beginning this activity, “test drive” the cars to ensure that they go at a constant speed and in a straight line for a distance of about 2 meters.
3. **Instruct students to map out a course (beginning and ending points), measure the distance between the points, and record the time it takes their cars to complete the course.** All information should be recorded in chart format.
4. **Using the formula of speed = distance/time, students should calculate the speed of their cars.** Measurements can be expressed as fractions and then converted to decimals.





5. Based on their calculated speeds, ask students to predict who will win an actual race between the cars. Students can then confirm their predictions by head-to-head competitions on the course.
6. If time and space permit, students may alter the course and repeat Steps 3-5 to see if the results change.
7. Upper level classes should now proceed on to measurements of acceleration. For accelerated motion, the same cars should be used but measured while moving along an inclined plane set up on the course. Add a long, inclined plane (wide board raised at one end) at the beginning or end of the course. The length of the course that runs on level ground need not be the same as that used in Step 3.
8. Students first race their cars up the ramp to demonstrate negative acceleration. Instruct students to record the time it takes just to get up the ramp from its beginning (=t). After running the cars on a level surface (but before beginning up the ramp), the cars will have an initial speed as measured in step 4 (=vi). As the cars move up the ramp, they will slow and eventually stop. (If the car does not come to a stop by the end of the board, simply increase the angle of the ramp until the car does stop at the end. You may wish to determine the required angle of the ramp prior to class.) The final speed (=vf) will then equal zero.
9. Students should use the following equation to determine their car's average acceleration (this value will be negative in sign):

   $$a = (vf - vi)/t$$

10. Students will then race their cars down the ramp to demonstrate positive acceleration. The time it takes to go down the ramp alone should be measured (=t). Since the cars begin to move from a standstill, the initial speed (=vi) is zero. To find the final speed (=vf), Step 3 should be repeated after the car has left the ramp. (It is best if the course used here is rather short.)
11. Students then use the same equation to determine their car's average acceleration:

    $$a = (vf - vi)/t$$

    This value will be positive in sign.

12. To observe the effects of the angle of the ramp on acceleration, the cars can be raced up the ramp as in Step 8. The distance of the point at which the car stops should be measured from the beginning of the ramp. Have students then measure the angle of the ramp with a protractor. The angle of the ramp can be increased and the new stopping distance measured. Students then summarize the data in a table that shows the angle of the ramp (at several settings) versus the stopping distance. Students should note that as the angle increases, the stopping distance decreases.

Academic Extensions/Modifications:

ELEMENTARY:

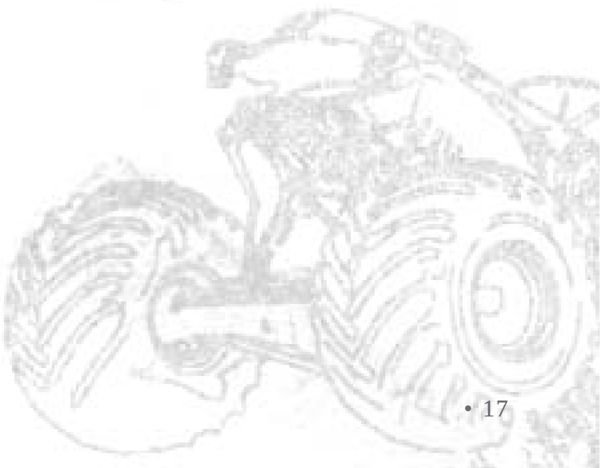
- In grades 4-6, it is appropriate for students to complete **Steps 1-6** to simply measure time and distance and compute speed as a fraction or ratio (e.g., 15ft/2seconds.) Students can also be given a compass to measure direction (i.e., “due north”). Although the direction information is not used in these calculations, it provides a basis for later explorations that require direction information (to compute vector quantities such as velocity and acceleration) and serves to reinforce geography concepts. The measurement of distances also provides an opportunity to discuss scales (English v. metric), conversion (from one scale to another), and units (and how they are expressed).

MIDDLE SCHOOL:

- In grades 7-8, as an extension for exceptionally gifted classes, students can plot distance versus time. (The slope gives you speed.) Students should also graph speed versus time, and measure the change in slope of the speed graphs to compute acceleration. If the acceleration is graphed against time, the graphs are linear. The important point to be noted is that in some cases (cars on a flat surface), a distance-time graph renders a linear function with a slope equal to the speed. In other cases (cars on a ramp), the same graph is non-linear, indicating a variable speed (accelerated motion). Further, a positively curved function shows an increase in speed (down the ramp) while a negatively curved function shows a decrease in speed (up the ramp).

Writing Prompts/Potential Discussion Questions:

1. While the car is moving on a flat surface, its speed is constant. If it moves 5 ft in 2 seconds, how far will it move in the next 2 seconds? In the next second after that?
2. While the car is moving down the ramp, its speed increases. What causes this increase in speed?
3. If a car is simply rolled down a ramp, it will eventually stop when it moves onto a level surface. Why?
4. When the car is moving up the ramp, it slows down. What causes it to slow down?
5. In high school physics, you will learn that speed is a scalar and velocity is a vector. Use the dictionary, or other sources, to explain the difference between a scalar and a vector. Give three examples of scalar quantities and three examples of vector quantities.



BRAIN BUCKET

Objectives:

To reinforce the concepts of force and motion as they relate to Monster Truck safety, students will design an "egg carrier" to protect an egg when dropped. Students will test the usefulness of their design by dropping the egg carrier from different heights and identifying the design features most useful in protecting the egg. Students will relate this information back to the design of safety helmets, or "brain buckets," worn by drivers.

Curriculum Connection:

This lesson serves as an excellent review of the scientific concepts of force, motion, and acceleration. The activity enables students to put scientific principles into practice and explore the subject of technological design.

Class Time:

One-to-two 50-minute class period(s) to plan and make the egg carriers, and one 50-minute class period to test egg carriers.

Exhibit Link:

This lesson works well as a pre- or post-exhibit activity. Given Monster Truck's concern for safety, drivers wear a lot of protective gear, the most important of which is a helmet, or "brain bucket." Issues related to helmet integrity and its ability to protect a driver's head will be explored in this "egg drop" exercise. After realizing the importance of helmets in the pre-activity, students visiting the exhibit will look closely at head protection in the Safety Seats video. The Strap-In simulation also reinforces the need to protect your head. As a post-activity, students can make notes regarding the materials and designs used for driver helmets, and apply that knowledge to their own "brain bucket" designs.

Materials Needed:

- raw eggs
- string
- Styrofoam peanuts
- cotton batting
- glue
- packing materials
- tape
- small boxes
- plastic straws
- cleaning materials to wipe up eggs when they break
- plastic sheet for egg testing area

Lesson Steps:

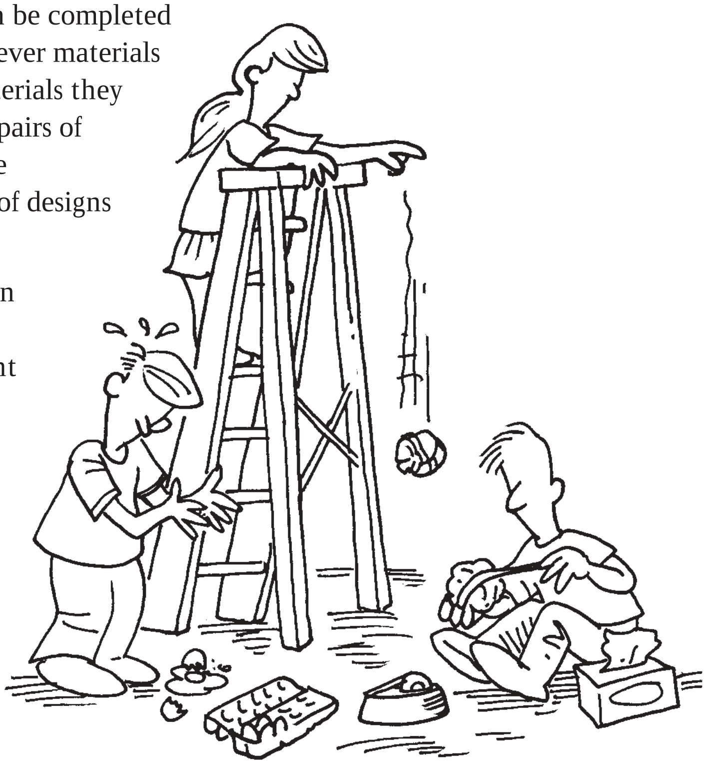
1. **In this lesson, students will use an egg drop exercise to simulate the forces of motion exerted on the human head during a Monster Truck crash.** It may be helpful to review the concepts of force and motion and how they affect objects during a crash prior to completing the lesson.
2. **Divide students into pairs or teams and provide each with a raw egg and a constant set of materials** (e.g., cotton batting, tape, small boxes, string, cloth, padding, etc). Inform students that their task is to use the materials provided to build a cocoon designed to protect their egg. Students should consider the design elements (size, shape, weight) of existing protective gear and take them into consideration for their "brain buckets." Provide 1-2 class periods for students to design, construct, and pre-test their "brain buckets." (More than one raw egg per team may be needed if testing is allowed.)
3. **Arrange for students to have safe access to drop their buckets from progressively taller heights.** The eggs should be examined after each drop to ensure integrity. Dropping the eggs from increasing heights will test designs. The design that protects the egg best from the greatest height wins. You may wish to videotape the egg drops for analysis during the activity conclusion.
4. **As a conclusion, ask students to analyze and discuss the design features that led to success or failure.**

Academic Extensions/Modifications:

ELEMENTARY:

- If time and materials permit, students can also be encouraged to add an artistic element to their “brain buckets.”

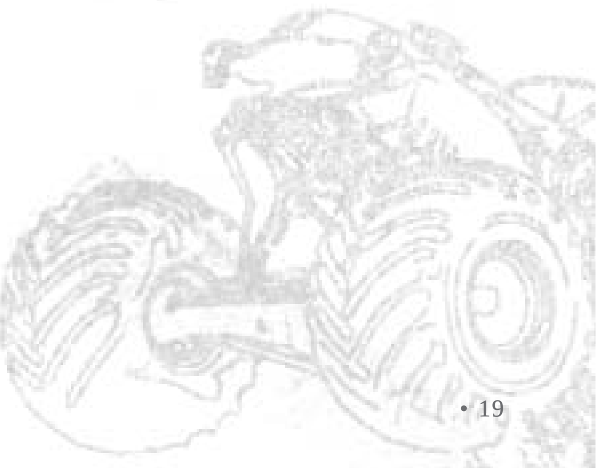
MIDDLE SCHOOL:



- For grades 7-8 or advanced classes, the same activity can be completed with the modification that students are free to use whatever materials they desire. Students can be encouraged to research materials they believe are best to use, and arrive at unique designs. As pairs of students lock into and “patent” a design, other teams are prevented from using it. This results in a larger number of designs for analysis of factors that result in success or failure.
- This exercise can be extended by taking successful design features (e.g., wrapping the egg in cotton) and systematically varying the feature (increasing the amount of cotton), while keeping other features constant. Subsequently, students can determine if the design feature actually provides additional protection.
- For advanced classes, the increase in height from which eggs are successfully dropped can be compared across design features to rank order their utility. For example, have some students double the amount of cotton used in their successful design, while other students double the amount of Styrofoam peanuts. If the eggs in the cotton can now survive a fall from twice as high, but the eggs in Styrofoam can now only survive a drop from 50% higher, it can be concluded that the cotton is more effective as a safety design than Styrofoam.

Writing Prompt/Potential Discussion Question:

After students have identified several features that help protect the eggs, ask them to identify those that might be most useful in designing a helmet for a Monster Truck driver. What additional factors must they consider when designing a helmet?



A MATTER OF MOMENTUM

Objective:

In this inquiry-based learning activity, students will observe cars (or balls) undergoing a collision and calculate the momenta of the cars/balls before and after the collision. Students will conclude that the total momenta before and after a collision is the same, thus observing the Law of Conservation of Momentum. As an extension, students can alter the weight of the cars/balls and observe the effect on the momentum of each after a collision.

Important Terms: *displacement, kinematics, Law of Conservation of Momentum, momentum, momenta, velocity, speed*

Exhibit Link:

The exhibit's Safety Lab looks closely at the precautions necessary when collisions (and the momenta associated with them) occur at Monster Truck meets. This lesson can be presented before or after visiting the exhibit.

Curriculum Connection:

A fundamental principle in physics is the Law of Conservation of Momentum. The momentum of an object is defined as the product of its mass and velocity. If two objects have the same mass and velocity, their momenta are equal. If friction is ignored and the objects collide head-on, they will both rebound in opposite directions but with the same speed. However, if one object has a greater momentum (because of a heavier mass and/or a greater velocity), both will move off in the direction of the object with greater momentum but with a smaller speed. The total momenta of the objects before and after the collision will be the same.

Class Time:

One 50-minute class period for teacher guided discussion and small group facilitated learning on how to measure the momentum. Additionally, one 50-minute class period is needed to measure the momentum of cars undergoing different types of collisions.

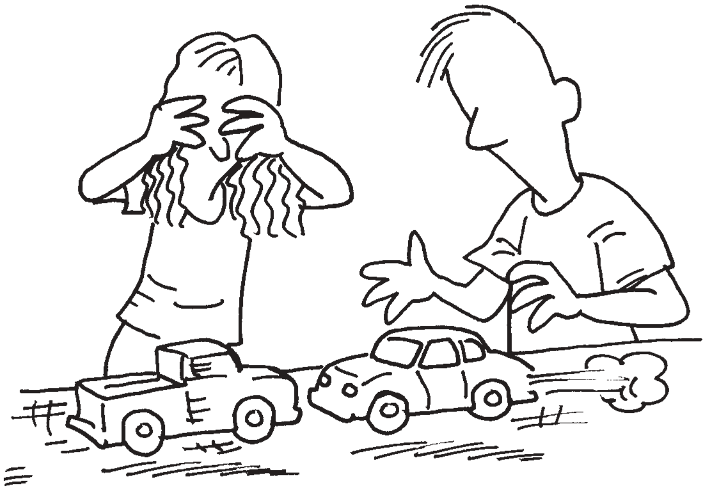
Materials Needed:

- rulers
- tape
- stop watches (or watch with a second hand)
- balance
- Hot Wheels® track
- washers
- long, wide boards for ramps
- small rubber balls to tape on the cars
- non-motorized cars (matchbox) of varying weights, or balls of similar and varying weights
- chart for recording data (teachers may wish to create their own chart handouts for this activity)

Note: You may wish to substitute balls in place of cars. You will need to provide balls of differing weights for students to choose from and use for the extension activity. If you choose to use balls instead of cars, be sure that the balls fit inside the Hot Wheels® track adequately.

Lesson Steps:

1. After introducing or reviewing the concepts of kinematics, provide students or teams with matchbox cars, rulers, clocks, small rubber balls, tape, and boards. If stopwatches are not available, the activity can be completed in a gym that permits extension of the distance (and time) so that a clock with a second hand sweep can be used and still provide reasonable measurements. If cars are used, instruct students to firmly tape the small rubber ball to the center of the front bumper of their car, making sure the ball does not touch the floor.
2. Instruct students to map out a course (beginning and ending points) with the Hot Wheels® track, and measure the distance between the points (about 4 feet is plenty). The board ramp should be set up at the edge of the beginning of the course (lay additional track on the board lined up with the course track) so that when released, the car will roll down the ramp and onto the beginning of the course.



3. **Students should record the time it takes for their car/ball to roll from the beginning to the end of the course.** All information should be recorded in chart format.
   Note: Students should start their stopwatches when the cars hit the beginning point of the course; time going down the ramp should NOT be included.
4. **Using the formula of speed = distance/time, students should calculate the speed of their cars.** Measurements can be expressed as fractions and then converted to decimals.
5. **After students have measured the velocity (speed in one direction) of their vehicles, they must weigh each car (with the ball attached.)** Using the balance, students should weigh and record the weight of each car. (Although mass is technically required to compute momentum, weight is a mathematically equivalent value.) Based on the measurements, students should pair up cars that have both the same or nearly similar weights *and* the same or nearly similar velocities.
6. **Next, students should compute and record the momentum of each car in their pair using the formula:**

   momentum = mass x velocity

   Note: Students will need to convert units used for mass and velocity to metric units.

7. **Set up an equal pair of board ramps, one at each end of the previously measured track course.** Starting at the opposite ends of the ramps, students should set up a head-to-head collision between their two cars/balls of equal or very similar weights and velocities. When the cars/balls run into each other, they rebound in opposite directions with the same speeds. Students should note that the cars rebound all the way back to their respective ramps.
8. **Have students repeat Step 7 in order to measure the speeds of the cars/balls after they have collided.** Since the length of the course is already known, it can be divided by 2 to find the distance each travels after the collision. Students then record the time starting with when the cars/balls collide to when they stop moving backwards. Using their data, students then calculate the speed (velocity) of the cars/balls after collision.
9. **To observe the Law of Conservation of Momentum in action, students use the formula again to calculate the momentum of each car/ball after collision.** Compared to their calculations from Step 6, no change will be noted if the cars/balls are equally matched for velocity and weight. Ask students to explain why this happens. (Answer: Following the law, the total momenta of both cars/balls before and after the collision are the same.)
10. **Distribute the reproducible to complete in class or as homework.** Answers: 1.a) momentum = 125,500; b) momentum = 60,250; c) Blue Thunder; 2) approx 35 mph; yes. 3) Radical Rescue would win. You would have to add 1029 lbs to Blue Thunder before it would win.

Academic Extensions/Modifications:

ELEMENTARY:

- This lesson can serve as an excellent inquiry-based learning activity for younger students to help them understand the concept of momentum. You may wish to create a large chart on the board that the class fills out as a whole after performing the experiment together. Depending on their skill levels, you may also wish to guide students through the formula calculations using the data that they collect.

MIDDLE SCHOOL:

- Reminding students of the formula for calculating momentum, ask them to predict what might happen to their cars/balls in a collision when one of the cars is heavier than the other. (If the cars/balls have similar velocities but quite different weights, both cars/balls will travel in the direction of the heavier car.) To observe this, instruct students to alter the weight of one of their cars by taping washers to it. Students should then repeat Steps 7 - 9 and observe what happens. (Balls of differing weights but similar velocities can also be used in place of the cars.) *Note:* When they are calculating momentum, remind students that momentum is a vector quantity, meaning that the direction of travel matters. Consequently, travel in one direction can be taken as having a positive velocity (and momentum), while travel in the opposite direction is assumed to have a negative velocity and momentum.
- For students in higher grades, you can extend this activity to a more advanced experiment in which cars with quite different speeds but similar weights collide with each other. The cars will both move off in the direction of the faster car. Students can measure the momentum of each car, before and after the collision, and confirm that there is no change in the total momenta of both cars together before and after the collision.
- If a light car collides with a heavier one, it will lose the contest. However, if the weight of the lighter car is increased, so is its momentum. At some point, it will have a momentum equal to the heavier car and the cars will rebound in opposite directions. If the weight is further increased, it will “win” in the collision contest. Students can be asked to predict how much weight must be added for their car to win. These predictions can be confirmed in a collision contest.

Writing Prompts/Potential Discussion Questions:

1. When cars collide, their momenta change. But what remains constant?
2. Sometimes when the cars collide, they rebound in opposite directions. Which car has the greater momentum?
3. Sometimes when the cars collide, they both move off in the same direction. Which car has the greater momentum? What happens to its speed?
4. If play dough is put on each car’s front bumper, they will stick together. What do you think happens to their momenta? This is an example of a “sticky” collision, called an “inelastic” collision. The momenta before the collision is zero because the two objects have the same mass but opposite velocities. After the collision, the total momenta MUST be zero, which happens in this case because both objects come to rest (if perfectly inelastic) and mass times zero is still zero. A good example of this is from football when two large linemen of roughly equal mass and opposite velocities collide head-on. Neither lineman moves very much! The same thing would happen with Monster Trucks.

Monster Momentum!

Now it's time to see what might happen if you match up Monster Trucks and normal cars in a head-to-head momentum battle! Using the information below and the formulas you have learned for calculating velocity and momentum, solve the following hypothetical problems.

Vehicle	Weight	Maximum Velocity
Blue Thunder	10,400 lbs	70 mph
Radical Rescue	10,000 lbs	Over 80 mph
Honda Accord	2,994 lbs	Over 120 mph

1. a. If Blue Thunder is moving at 60 mph, what is its momentum?

   b. If an Accord is moving at 100 mph, what is its momentum?

   c. If they have a head-on collision, who will win? Why?

2. If Blue Thunder is moving at 10 mph, how fast would the Honda have to move to win a head-to-head collision? Can the Honda go that fast?

3. If Radical Rescue is moving at 80 mph and collides with Blue Thunder moving at 70 mph, who would win?

   How much weight would you have to add to the losing truck before it would win?

Glossary

acceleration: a change in the direction or magnitude (speed) of an object.

average acceleration: can be computed with this equation: $a = (v_f - v_i)/t$, where "a" is the acceleration, "v_i" is the initial speed, "v_f" is the final speed, and "t" is the time it takes to change speed.

active restraint: a type of safety equipment activated by the vehicle passenger, designed to restrict the movement of drivers and/or passengers. (ex. seat belt, child safety seat restraints)

adiabatic process: a thermodynamic process in which no heat is lost or gained. The power stroke in an engine occurs so rapidly that little heat is lost; therefore, the power stroke is considered an adiabatic process.

angular acceleration: the change in angular velocity divided by time.

angular momentum: the product of the moment of inertia and its angular velocity.

angular velocity: for rotating objects, the amount of rotation expressed in radians/time.

BDC: the measurement of a piston at the bottom of its travel in the cylinder.

bore: the diameter of a cylinder in an engine.

camshaft: the component that controls the opening and closing of valves in an engine.

capacity: the amount a container or object can hold or contain; e.g., the amount of fuel a Monster Truck's fuel tank can hold.

Carnot engine: an ideal engine in which each process is reversible.

circumference: the distance around a circle.

coefficient of friction: the ratio of the force of friction to the normal force when one surface is sliding (or attempting to slide) over another surface.

Combined Gas Law: expression relating pressure, volume, and temperature before and after an event when the moles of gas remain constant: $P_1V_1/T_1 = P_2V_2/T_2$.

consume: to take in or use up; burn, as an automobile engine burns fuel to move a vehicle.

crankshaft: device that changes the reciprocating motion of the pistons to rotating motion; contains the area where the connecting rods are fastened and also the area where the flywheel and engine drive pulley are connected.

customary system of measurement: a measurement system used in the United States, which includes basic units such as feet and gallons.

dashboard: the panel under a vehicle's front windshield, on which an automobile's fuel gauge and other control instruments display.

diameter: a line segment that passes through a circle's center to connect two points on the circle.

displacement: the distance between two points. In auto technology, the volume that a piston displaces in a cylinder as it moves from TDC to BDC.

distance: the straight-line measurement between two points.

engine block: the metal foundation containing the parts of an internal-combustion engine; includes cylinders, coolant passages, oil passages, etc.

exhaust valve: the valve that opens to allow all the vapors inside the cylinder to be removed from the engine on the exhaust stroke.

eye wash station: the area in a lab specifically designed for washing any foreign matter from the eyes; a station can be plumbed into the water system or may use separate bottles of saline solution.

fire extinguisher: hand-held fire fighting equipment designed with specific chemicals to put out small fires.

First Law of Thermodynamics: the change in the internal energy of a system equals the difference between the heat added to the system and work done by the system.

four-stroke engine: an internal-combustion engine developed by Nikolaus Otto in 1867. A four-stroke engine works as follows: as a piston moves down, the intake valve(s) opens, allowing a mixture of fuel and air to flow into the cylinder (intake stroke). After the intake valve(s) closes, the piston moves upwards, compressing the mixture and increasing its temperature (compression stroke). If this mixture is ignited, the piston is driven downwards, making the drive shaft rotate (power stroke). Lastly, the piston moves upwards while the exhaust valve(s) opens, allowing exhaust gasses to be pushed out of the cylinder.

gauge: a measuring device.

horsepower: the measurement of the engine's ability to perform work.

intake valve: valve that opens to allow fuel and air to be drawn into the combustion chamber.

jack stands: safety devices designed to be placed under a vehicle that has been jacked up to prevent the vehicle from falling while work is being performed.

kinematics: the description of motion in terms of distance, speed, velocity, and acceleration.

kinetic energy: the energy an object has due to its motion.

Law of Conservation of Energy: states that the total energy in a system both before and after a process is constant.

Law of Conservation of Momentum: In an isolated system, if the momenta of two objects are measured before and after colliding, the total momenta will be the same.

Material Safety Data Sheets (MSDS): information provided by chemical manufacturers that have instructions on how to protect users and the environment in case of a spill; also contains instructions on how to clean up and dispose of material that has been spilled.

metric: the decimal-based measurement system used most often in the United States during scientific pursuits; basic units include meters and liters.

moment of inertia: the product of the mass of a rotating object and its radius squared. The exact equation depends on the shape of the object, but for drive shafts or tires, it is given by this equation: $MR^2/2$ where M is the mass of the rotating object and R is its radius. The moment depends on the mass of the rotating object and on how far from the axis of rotation the mass is. If the mass is close to the axis of rotation, the moment is small. If the mass is far from the axis of rotation, the moment is large.

momentum: the product of an object's speed and its mass; $p = mv$. (plural: momenta)

net force: the sum of all the forces acting on an object.

passive restraint: a type of safety equipment designed to restrict the movement of drivers and/or passengers; activates automatically to protect the occupant of a vehicle. (ex. air bags, automatic shoulder harness)

pi: a ratio of a circle's circumference to its diameter, equal to about 3.14 (or 3).

piston stroke: the movement of the piston from the bottom of its travel to the top of its travel.

piston: the component in an engine that is driven up and down in the cylinder and is connected to the crankshaft by the connecting rod.

potential energy: the energy an object has due to its position.

projectile motion: the motion of an object in a gravitational field.

radius: a line segment that connects a circle's center to any point on the circle; it is half the size of the diameter.

rate: the measure of how fast something is changing; when the distance an object moves is divided by the time it takes to travel that distance, the quotient equals the object's average rate of speed, e.g. feet per second.

spark plugs: devices that, upon receiving power, ignite the fuel/air in the combustion chamber causing the piston to move down in the cylinder, and thus causing the crankshaft to turn.

speed: the rate of change in an object's position over time (speed = distance/time).

Supplemental Restraint System (SRS): restraints designed to help keep drivers and passengers in their respective seats in the event of an accident. (ex. air bags)

TDC: the measurement of the piston at the top of its travel in the cylinder.

timing chain or belt: a device that coordinates the movement of the crankshaft with the camshaft to ensure that pistons and valves are working together.

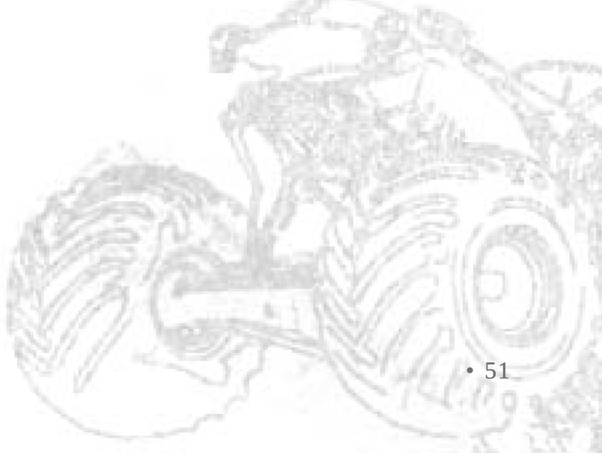
torque: a force applied to some point other than the center of an object's mass, causing movement or rotation.

unibody design: a chassis design that includes a floor pan and a small sub frame section in the front and rear.

variable: a quantity that may have more than one value.

velocity: speed in a particular direction. (e.g., 50 mph due north) If an object does not change its direction of motion, then its speed is the same as its velocity.

work: the transfer of energy to a body by the application of a force that moves the body in the direction of the force ($W = Fd$).



Additional Resources and Web Sites

Teacher References

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Hewitt, P. *Conceptual Physics*. 8th Edition. © 1998 by Benjamin Cummings.

Zitzewitz, P. *Glencoe Physics: Principles and Problems*. © 2002 by Glencoe/McGraw Hill.

Monster Truck Racing by Scott D. Johnston (Capstone Press, 1994)
This book is a clear, concise, and colorful introduction to Monster Truck racing for grades 4-6 students. The author describes the history, science, economics, and sport of Monster Truck racing. The book includes many photographs, a glossary, and a list of additional resources.

Web Sites

http://www.getbehindthewheel.com/index.htm
This web site includes links to the web sites of automotive corporations, whose sites include detailed information about dozens of automobiles, including photographs you might wish to show students when discussing vehicles' relative fuel capacities.

http://www.its-about-time.com
Visit this site to learn more about the popular textbook line Active Physics and other supplemental kits available to teach math and science concepts to grades 6-12.

http://www.monstermania.com
Find information about upcoming events, Monster Mania news, and links to Monster Truck Home pages here.

http://monstertruckracing.com.
Access high-quality photographs of all your favorite trucks, plus read Truck facts and stats.

http://www.physicsclassroom.com/
A good resource for learning basic physics concepts and reviewing them in a Physics Tutorial. Also includes practice problems and a multimedia section where students can view physics in action.

http://www.sciencejoywagon.com/physicszone/
The Physics Zone presents introductory level, algebra-based physics concepts in a multimedia format that is engaging as well as informative.

http://www.truckworld.com/index.html
Read monthly articles written by experts and view the Show and Events section for all the latest results.

http://ushra.com/#
Official site of the USHRA, this resource provides current Monster Truck results, a photo gallery, official news and headlines, driver bios and more. A true Monster Truck fan must-see!