



## **PUMP IT UP!**

### **ANALYSIS OF TIRE PRESSURE PERFORMANCE**

#### **INTRODUCTION**

Tires are a ubiquitous part of transportation. An essential component of the wheel, the tire helps ensure safe traveling for ground vehicles. However, tires must be periodically checked and maintained at a proper pressure to guarantee optimal performance. In this lesson, students will learn why pumping tires to the correct pressure is important. They will also understand why using the wrong tire pressure is detrimental. Students will learn about the variables that determine optimal tire pressure. During the class discussion, students will learn about how often pressure should be checked.

#### **LESSON OVERVIEW**

**Grade Level & Subject:** 5-8; Physics, Math,

**Length:** 1 class period

#### **Objectives:**

After completing this lesson, students will be able to:

- Understand the importance of proper tire pressure
- Explain how excessively low or high pressures affect tire performance
- Describe what factors affect optimal tire pressure
- Determine when to check tire pressure

#### **National Standards Addressed:**

This lesson addresses the following National Science Education Standards.<sup>1</sup>

- **Content Standard: [DATA ANALYSIS AND PROBABILITY](#)**  
As a result of their activities in grades 6-8 all students should:
  - Select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatter plots.
- **Content Standard: [NS.5-8.2 PHYSICAL SCIENCE](#)**  
As a result of their activities in grades 5-8, all students should develop an understanding:
  - Motions and forces
  - Transfer of energy
- **Content Standard: [NS.5-8.6 PERSONAL AND SOCIAL PERSPECTIVES](#)**

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<sup>1</sup> <http://www.education-world.com/standards/>

As a result of their activities in grades 5-8, all students should develop understanding:

- Populations, resources, and environments
- Science and technology in society

### Materials Needed:

- At least two bicycles (if more, preferably an even number of bicycles and if possible, bicycles should be identical pairs)\*
- At least two stopwatches/as many stopwatches as bicycles
- Access to sports field or oval running track
- Bicycle helmets
- Bike Pump with gauge
- Overhead projector
- Colored Pencils
- **Reproducible #1 – Time Trial Tickets**
- **Reproducible #2 – Example Diagrams**
- **Reproducible #3 – Tire Pressure Time Trials**

\*Having identical pairs of bikes will limit external variability and increase the precision of the class graphs

### Assessment:

Students will be assessed through the following activities:

- Active participation in class discussions
- Partaking in lap time trials and class graph compilation

## LESSON BACKGROUND

### Relevant Vocabulary:

- **Energy Efficiency (mechanical physics):** The relative percent of initial energy in a system that is converted into kinetic energy and not lost to heat, sound, or other minor energy losses<sup>2</sup>
- **Friction:** The force that resists relative motion between two bodies in contact<sup>3</sup>
- **Fuel Economy:** The rate at which fuel is consumed in an automobile, generally defined in terms of distance traveled per unit volume of fuel expended<sup>4</sup>
- **Pressure (physics):** The force or thrust exerted over a surface divided by its area<sup>5</sup>
- **Traction:** The adhesive friction of a body on the surface on which it moves<sup>6</sup>

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<sup>2</sup> Deutsch, John. "Conservation of Mechanical Energy." *Department of Physics at UC Santa Cruz | Grad School Physics*. University of California Santa Cruz, 2 Feb. 2003. Web. 31 Mar. 2011.

<http://physics.ucsc.edu/~josh/6A/book/work/node17.html>.

<sup>3</sup> "Friction Entry." *Merriam-Webster Online Dictionary*. Retrieved 31 March 2011 from <http://www.merriam-webster.com/dictionary/friction>

<sup>4</sup> "Basic Information | Fuel Economy | US EPA." *US Environmental Protection Agency*. US EPA, 4 Mar. 2011. Web. 31 Mar. 2011. <http://www.epa.gov/fueleconomy/basicinformation.htm>.

<sup>5</sup> "Pressure Entry." *Merriam-Webster Online Dictionary*. Retrieved 31 March 2011 from <http://www.merriam-webster.com/dictionary/pressure>

## Background Information:

Automobile **fuel economy** is a function of the vehicle's weight, aerodynamic coefficient, engine power, and fuel content, among other variables.<sup>7</sup> Although most of these variables cannot be adjusted by the average consumer (i.e. the typical car buyer will not install a turbocharger in their engine to increase efficiency or modify the chassis to make it more streamlined), there are some maintenance tasks that car owners can regularly perform to ensure that their fuel economy is maximized. These tasks include changing the oil, keeping the engine properly tuned, and maintaining proper tire **pressure**.<sup>8</sup> If any of these maintenance routines are not carried out, fuel economy could be diminished. Of all automobile maintenance tasks, maintaining the proper tire pressure is often touted as being the simplest way of maximizing fuel economy.

Pumping a tire to the correct pressure allows for optimal contact between the tire and the ground. If the tire is not inflated enough, then too much rubber will be in contact with the ground increasing **friction** and increasing the amount of work the car will need to do in order to move. If a car's tires are constantly underinflated, the tires and engine may be subject to increased wear. Significantly underinflated tires may also lead to other issues such as overheating tires and tread separation. On the other hand, overinflating the tire may cause the tires to bounce. As a result, the car loses **traction** and some energy will not be fully translated into forward motion. Maintaining the tire pressure within an optimal range will help to limit both friction and bouncing.<sup>9</sup>

Of course, keeping tires at the right pressure is not important only for automobiles. Bicycles, wheelbarrows, and other machinery that use rubber wheeled tires must be pumped to an ideal pressure. Otherwise, using them would become cumbersome. A bicycle with a partially inflated tire will be harder to pedal than one that is pumped to the correct pressure. Likewise, a loaded wheelbarrow will be difficult to push if its wheel(s) is/are flat.

The recommended tire pressure for any vehicle depends on multiple factors including the weight of the vehicle and occupants, the conditions in which the vehicle will be driven, and the type and manufacturer of the tire.<sup>10</sup> As a result, ideal tire pressure ranges will vary greatly between people and vehicles. For the purpose of this experiment, it is recommended that you use the most general tire pressures ratings for the bicycle time trial activity (see below). However, you may use more specific tire pressures to account for each individual's weight. This will be more time consuming, though, as you will need to release air and pump up the tire depending on the bicycle rider. Tire manufacturers typically will include specific tire pressure information on the packaging.

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<sup>6</sup> "Traction Entry." *Merriam-Webster Online Dictionary*. Retrieved 31 March 2011 from <http://www.merriam-webster.com/dictionary/traction>

<sup>7</sup> Gautam, Suman, "What Factors Affect Average Fuel Economy of US Passenger Vehicles?" (2010). *Honors Projects*. Paper 104. [http://digitalcommons.iwu.edu/econ\\_honproj/104](http://digitalcommons.iwu.edu/econ_honproj/104)

<sup>8</sup> "Gas Mileage Tips - Keeping Your Vehicle in Shape." *Fuel Economy*. US Department of Energy, 31 Mar. 2011. Web. 31 Mar. 2011. <http://www.fueleconomy.gov/feg/maintain.shtml>.

<sup>9</sup> Robert A. Morse, "Determining the Effect of Tire Pressure on Rolling Resistance", *TPT*, Vol. 26, # 4, p. 225, April 1988.

<sup>10</sup> "What's Your PSI, A Tire Safety Quiz for Motorcyclists." *Home | National Highway Traffic Safety Administration (NHTSA)*. NHTSA. Web. 01 Apr. 2011. <http://www.nhtsa.gov/people/injury/pedbimot/motorcycle/psimotorcycle/pages/McycleTireSafTips.htm>.

General tire pressure ranges are as follows:<sup>11</sup>

Mountain Bikes: 50 to 60 psi

One to Three Speed Bikes: 40 to 50 psi

Road Bikes: 75 to 100 psi

**Resources:**

- **Keeping Your Car In Shape**— *U.S. Department of Energy*:  
<http://www.fueleconomy.gov/feg/maintain.shtml>
- **Biking Resources** – *Michigan State University*:  
[http://www.bikes.msu.edu/content/biking\\_resources.html](http://www.bikes.msu.edu/content/biking_resources.html)

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<sup>11</sup> "Biking Resources | MSU Bikes | Physical Plant Division." *MSU Bikes | Physical Plant Division | Michigan State University*. Michigan State University, 2009. Web. 31 Mar. 2011.  
[http://www.bikes.msu.edu/content/biking\\_resources.html](http://www.bikes.msu.edu/content/biking_resources.html).

## LESSON STEPS

### Teacher Preparation Steps:

1. Make sure your class has access to an open field or track during the designated class period in which you will be teaching the lesson plan.
2. Mark the bikes with a number or letter, e.g. Bike #1, Bike A, etc.
3. Drain every other bike (Bike #2, Bike #4, or Bike B, Bike D etc.) to about 70% of the lowest recommended pressure. Pump the rest of the bikes to the maximum recommended pressure. This number can often be found on the side of the tire.
4. Print out **Reproducible #1 – Time Trial Tickets** on cardstock or thick paper and cut the sheet into individual tickets. Each student will be given one ticket. Make additional sheets with higher numbers as needed.
5. Print **Reproducible #2 – Example Diagrams** as an overhead transparency.
6. Print out enough copies of **Reproducible #3 – Tire Pressure Time Trials** for each student. Print the graph paper on the backside of the sheet.

### Warm-up: *Tire Pressure Science*

The warm-up will consist of a series of critical thinking discussion questions to encourage students to investigate the importance of proper tire pressure.

1. Tell your students that the class will be learning about the importance of tire pressure and how it affects performance. Proceed to ask the following questions.
  - a. Why do you think it is important for rubber tires to be inflated to the correct pressure? *It helps to increase efficiency or prevent loss of efficiency. If the tires in an automobile are not inflated the fuel economy can be negatively affected, costing the owner of the vehicle more money. Also, since a higher use of gas results in the release of increased emissions, the environment is also negatively impacted by tires that are not inflated to the correct pressure.*
  - b. Why do you believe efficiency and fuel economy is affected by tire pressure? *Tire pressure determines the amount of contact that the tire has with groundcover. More contact between the tire and groundcover means more friction. As a result, more work needs to be put in to turn the tire and drive the vehicle. In the case of cars and trucks, the engine will need to expend more fuel. If a bicyclist rides on a deflated tire, he will need to pedal harder.*
  - c. Why do tires have recommended ranges of pressure? What might happen if a tire is pumped above the recommended range? *The most obvious answer is that the tire could burst. But, generally tires are engineered to withstand pressures greater than the recommended ranges. Nonetheless, pumping a tire beyond its recommended range will cause the tire to bounce. This reduces traction which can be dangerous when cornering and may affect stopping distances.*
  - d. What factors might affect the optimal tire pressure? *Temperature (Students may be familiar with the ideal gas law which is generally taught as a chemistry subject.) The ideal gas law,  $PV=nRT$ , tells us that if volume remains constant but temperature fluctuates, then the pressure is directly proportional to the temperature, i.e. if the temperature increases, so does pressure, and if temperature decreases, so does pressure. Weight of the vehicle, occupants, and cargo. Heavier loads mean more tire-surface contact. Terrain. Typically, off road driving will require lower tire pressures to increase traction. Type and manufacturer of the tire. Not all tires are made the same. Two sport tires made by two entirely different manufacturers will most likely have significantly different pressure recommendations. Tire*

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*manufacturers will usually include tire pressure information on the packaging or the tire itself.*

### **Activity One: *Time Trials***

The activity for this lesson plan will offer students a hands-on approach for learning about tire pressure and its effect on performance and efficiency.

1. Take your class out to the field/track. Tell the students that they will be riding laps around the field/track. Each student will be riding two laps. For the first lap, students will ride on a bike with properly inflated tires (Bike #1, etc.). For the second lap, students will ride on a bike with partially deflated tires (Bike #2, etc.). Students will be timed with a stopwatch each lap. The goal is to post the quickest time possible during both trials. Students should take a break between each lap to rest and regain their energy. This way, each trial is representative of their best time.
2. Ask for volunteers first to do their time trials. Students should bike the first lap on the properly inflated tires. The first lap is the control lap and establishes students' baseline time. If only two bikes are available, students will need to ride in succession. Before riding, give each student a numbered ticket (See **Reproducible #1 – Time Trial Tickets**). This will be used to track the order in which the bikes were ridden. Additionally, the numbers will be used to graph the results of the activity. Students who are not currently riding the bikes will time the ones who are riding.
3. After students complete a lap, ask them to mark it on the ticket. When all the students have completed both laps, take the tickets from all the students, and walk the class back to the classroom.
4. On the blackboard, tabulate all the data using a three column table. The left column will include the number assigned to each student, and the middle and right column will be the student's respective lap times. See **Reproducible #2 – Example Diagrams** for an example of what the table may look like.
5. Then hand out the worksheet **Reproducible #3 – Tire Pressure Time Trials**. Ask the students to copy the data from the blackboard onto the worksheet and complete the rest of the table using the equations given. On the graph paper, the students should graph the lap time trials for the whole class. The x-axis will be the ticket number of each student. The y-axis will be the lap time in seconds. Both the properly inflated and partially deflated tire data will be included in the same graph. Show students **Reproducible #2 – Example Diagrams** for an example of the graph. If possible, have students use a different color for each data set. Optionally, students may also produce other graphs to analyze the data. For example, if the class used several types of bikes with different tire diameters you can separate graphs by bike type or tire diameter.
6. Go over the worksheet answers when all the students are finished. *Results will vary for each class.*

### **Wrap Up: *Discussion***

After you have gone over the answers with the class, begin a class discussion about the results from the activity.

1. Do you notice a trend between the times posted on the properly inflated tires and the partially deflated tires? *On average, lap times for properly inflated tires should have been less than the*

- partially deflated tires. On an individual basis, the disparity in lap times may vary widely. The difference in lap times can be visually estimated by looking at the gap between two graph points for a particular student.*
- 2. Is there a trend between the beginning trials and the final trials? If so, why do you think this was? There may have been a gradual increase in lap times between the first trials and last trials. This is likely due to the fact that the tires slowly lose pressure with each successive trial.*
  - 3. How difficult was pedaling the partially deflated bike compared to the bike with properly inflated tires? The partially deflated bike would be noticeably more difficult to ride than the bike with properly inflated tires. Even if a student was able to match or beat his baseline lap time with the deflated tire bike, he would have expended a lot more energy and probably would have been more tired afterwards.*
  - 4. How was this activity relevant to the topic of tire pressure and performance? How does it relate to fuel economy? It is important to keep a car's tire pressure at an optimal level. This ensures the best fuel economy. The activity demonstrated how underinflated tires can detrimentally affect energy efficiency.*
  - 5. When is it important to check tire pressure (particularly in cars)? Tire pressure should be checked periodically, every couple of weeks, more frequently if driving on rough terrain. Tire pressure should also be checked at the beginning/end of each season. Since tire pressure is greatly affected by temperature, you will want to know if the pressure in your tire has dropped and if more air needs to be added.*

### **Extension Activities/Projects:**

1. The same experiment can be carried out with wheelbarrows instead of bikes. You can organize wheelbarrow sprints in which identical wheelbarrows are filled with equal amounts of bricks or sand, except the tires of one wheelbarrow are deflated. Then two students will line up at the starting line and race as fast as possible to the finish line (100 yards). Note which student won and the times of both. Then the students can switch places and race again.
2. Since the experiment uses only two distinct data points from each student the results may not be considered statistically sound. The presence of numerous external variables also greatly increases the range of error. To improve the statistical significance of the experiment, the activity could be expanded to include more data. Students could ride the bikes for several more laps on multiple days. Additional data will help to bolster the conclusions on how tire pressure affects performance.

## **CONCLUSION**

Tire pressure plays a substantial role in energy efficiency and fuel economy. This lesson plan taught students the effects of not maintaining proper tire pressure on a vehicle. Students also learned what factors affect the optimal tire pressure and when to check tire pressure. After completing this lesson students will have gained an appreciation for the importance of tire pressure. They will be able to transfer this knowledge to benefit their daily lifestyles whether it is the next time they go for a bike trip or in a few years when they get their driver's license.

## **LESSON PLAN CREDITS**

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## EXAMPLE DIAGRAMS

Student Ticket #	Properly Inflated Tire Lap Time	Partially Deflated Tire Lap Time
1	60	70
2	55	67
3	30	36
4	45	80
5	59	79
6	41	44
7	60	65
8	51	50
9	37	46
10	49	55
11	52	57
12	63	71





