National Aeronautics and Space Administration

GRADES 5-12

Space Shuttle Tires

structures and materials

Aeronautics
Research
Mission
Directorate

Museum in a BOX Series

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Space Shuttle Tires

Lesson Overview

Through demonstration and math activities, students will learn about tire technology and the effects of air pressure. A section of tire from the Space Shuttle, a light truck and a bicycle are provided for students to compare and contrast. In addition, math activities are provided for students to complete and discuss the basic formulas for air pressure, circumference and the number of revolutions of a tire over a given distance.

(Photo courtesy of the Dryden Flight Research Center)

Space Shuttle Columbia's first landing was at NASA's Dryden Flight Research Center, located at Edwards Air Force Base, CA.

Objectives

1. By observing the tire sections from the Space Shuttle, a truck and a bicycle, students will identify the parts of each tire and note the differences between them.
2. Students will determine the tread depth of a tire using a penny or a quarter.
3. After reviewing Tire Basics, students will identify the information stamped on the sidewalls of tires found on vehicles in a parking lot.
4. Students will use mathematical formulas to determine the diameter and circumference of a tire, as well as the number of revolutions made over a given distance.
5. Students will calculate how tire pressure can impact the life of a tire along with its affect on fuel efficiency.

Materials:

Included in MIB

Space Shuttle tire section
Truck tire section
Bicycle tire section

Provided by User

United States Coins: one penny and one quarter for each group of 3 to 5 students

GRADES 5-12

Time Requirements: 2 hours 50 minutes

Background

Landing the Shuttle

Although the Space Shuttle departs Earth vertically as a rocket, it lands horizontally, like an airplane. This requires a landing gear system comprised of struts, shock absorbers and most importantly to these activities, tires. The Shuttle normally lands at the Kennedy Space Center in Florida, using Edwards Air Force Base in California as an alternate runway during periods of unsuitable weather.

To land, the orbiter (which is the part of the Space Shuttle remaining after the solid rocket boosters and fuel tank have jettisoned upon launch), aligns with the runway. It begins a steep descent with its nose angled as much as 19 degrees down from horizontal. This 'glide slope' as it is known is nearly seven times steeper than the average commercial airliner landing which causes the Shuttle to descend toward the runway approximately 20 times faster. At about 610 meters (2,000 feet) above the ground, the Shuttle commander raises the nose, which slows both the rate of descent and airspeed in preparation for touchdown. At approximately 75 meters (250 feet) above the ground, the speed will have slowed to less than 556 km/hr (300 kts/345mph) and the landing gear is deployed and locked into place.

At touchdown, the main landing gear tires contact the runway first at approximately 354 km/hr (191 kts/220mph). Next, the nose gear lowers slowly as the orbiter loses speed. If necessary, a drag shoot can be deployed to assist in slowing the orbiter as well as maintaining directional control down the runway.

Shuttle Tires

The Shuttle has two main landing gear, which consist of two tires each. There are also two tires on the nose landing gear, for a total of six tires.

Like most aircraft tires, the Space Shuttle tires are filled with Nitrogen because of its stability at different altitudes and temperatures. Also, Nitrogen molecules are larger than Oxygen molecules, which means Nitrogen escapes less easily from the tires, resulting in a more gradual loss of pressure over time. Nitrogen is also non-flammable which prevents problems should a tire puncture upon landing.

When landing, the orbiter weighs approximately 109,000 kg (240,000 lbs). Because of this, shuttle tires are inflated to a much higher pressure than a small airliner or car. The main gear tires are inflated to 315 psi while the nose gear is inflated to 300 psi. The main gear tires can only be used one time, while the nose gear tires can be used for two landings.

Tire Basics

Every tire manufactured in the United States is required to have its designation stamped into the sidewall of the tire.

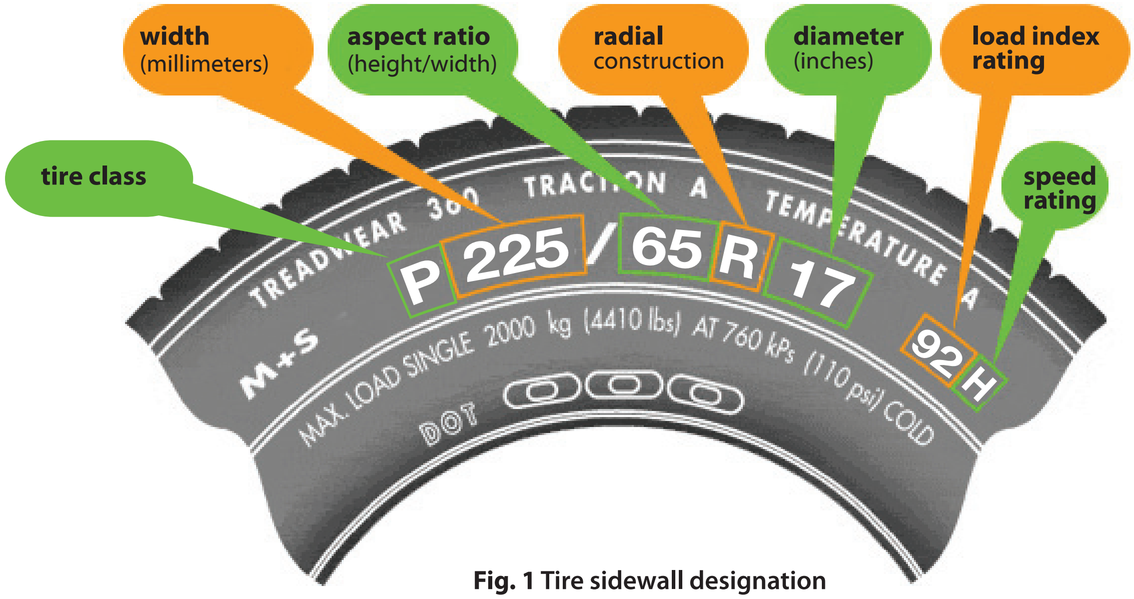


Fig. 1 Tire sidewall designation

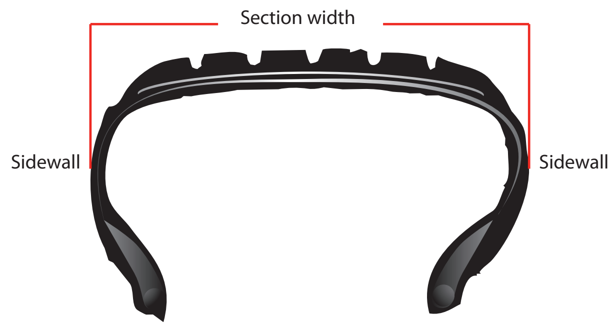


Fig. 2 Tire cross section

In this example you can see the following designation on the tire: P225/65R16 92H

- **P** designates the tire's class. In this example, "P" indicates that the tire is a passenger car tire. An "LT" would designate it as a light truck tire.
- **225** is the tire's section width measured in millimeters. This measurement is taken from sidewall to sidewall. In this example, the section width of the tire is 225mm.
- **65** is the aspect ratio of the tire. The aspect ratio refers to the height of the sidewall as a percentage of the section width.
- **R** refers to the tire construction. In this example the tire is a radial tire. Although rare, you may also see the letter C, which refers to a cross-ply tire.
- **17** refers to the wheel diameter in inches.
- **92** refers to the load index for the tire. Load index ranges from 0 to 279 and corresponds with the load-carrying capacity of a tire. Passenger car tire load indices typically range from 75 to 105. (See the Load Index Table, Fig. 10 in the Reference Material Section.)
- **H** indicates the speed rating for the tire, which is the maximum speed for which the tire is allowed to travel per the manufacturer's recommendation.

Activity 1 Comparing Tires

GRADES 5-12

Time Requirement: 30 minutes

Materials:

In the Box

Tire Sections:
Space Shuttle
Truck
Bicycle

Worksheets

Venn Diagram
(Worksheet 1)

Reference Materials

Figure 1
Figure 2
Figure 3
Figure 4
Figure 5

Key Terms:

Bead
Chafer
Filler
Liner
Nylon Belt
Plies
Sidewall
Steel Belt
Tread

Objective:

Observing the tire sections from the Space Shuttle, a truck and a bicycle, students will identify the parts of each tire and note their differences.

Img. 1 Tire Cross Sections

Activity Overview:

In this activity you will use the pieces of tire provided to explore the differences between tires used on three different vehicles: a bicycle, a pickup truck and the Space Shuttle. You can either keep the students in one group or divide them into three groups, with each group getting a tire section.

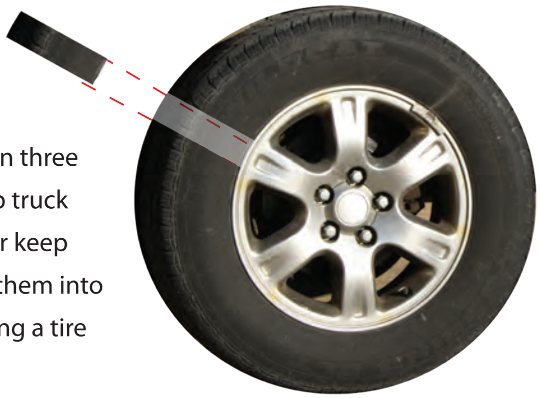


Fig. 3 Tire with cross section

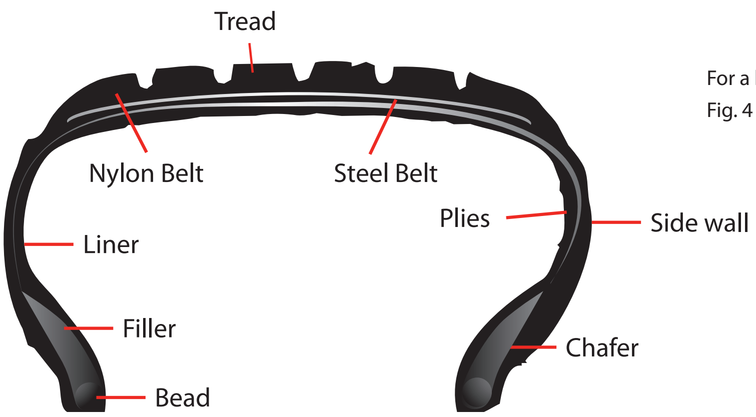
Activity:

1. Examine the three tires provided (shuttle, truck, and bicycle).

Hold up each piece of tire and tell the students which one belongs to which vehicle. Explain that each piece of tire is just a cross-section of the entire tire. (A cross-section is a slice of tire cut perpendicular to the wheel and extracted from the whole tire so we can easily see what the tire is made of and how it is constructed.) Using the "Tire Cross-Section" (Fig. 3) diagram, demonstrate how the cross-section relates to the whole tire.

2. Identify the parts of each tire.

Display the "Parts of a Tire" (Fig. 4) diagram. Hold the shuttle tire segment up and point out the parts of the tire mentioned on the diagram, explaining each term.



For a list of terms and definitions, see Fig. 4 in the reference materials section

Fig. 4 Parts of a tire

3. Compare and contrast the parts of the three tires.

Pass the tire pieces around so that every student has the opportunity to feel and see each piece.

Encourage students to examine the tires closely and to take note of similarities and differences.

Point out that some tires have components that others do not. For example, the bicycle tire has a bead, but not a steel belt.

Suggest the students think about the vehicle each piece of tire supports while they are examining its tire.

If necessary, point out that larger/heavier vehicles require larger tires.

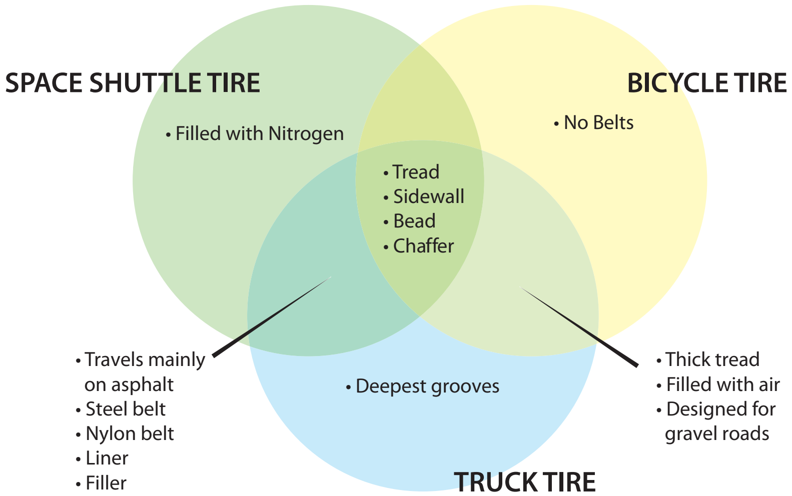


Fig. 5 Venn Diagram

Discussion Points:

If you have access to a white board, chalk board or large pad of paper, draw or display the following Venn diagram. If not, use the blank diagram provided in the worksheet section. Discuss with the students the differences and similarities of the tires, placing the items on the chart in their appropriate locations. Your finished diagram should look similar to Fig. 5.

1. How are the tires similar?

2. How are the tires different?

3. Why do you think the tires are created differently?

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Properties and changes of properties in matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

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NATIONAL MATH STANDARDS K-12

NUMBER AND OPERATIONS

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Understand meanings of operations and how they relate to one another
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ALGEBRA

- Represent and analyze mathematical situations and structures using algebraic symbols
- Use mathematical models to represent and understand quantitative relationships

MEASUREMENT

- Understand measurable attributes of objects and the units, systems, and processes of measurement
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DATA ANALYSIS AND PROBABILITY

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

- Problem Solving
- Communication
- Connections
- Representation

MUSEUM IN A BOX

Activity 2 Measuring Tire Tread

GRADES 5-12 **Time Requirements:** 20 minutes

Materials:

In the Box

Tire Sections:
Space Shuttle
Truck
Bicycle

Provided by User

United States Coins: one penny and one quarter for each group

Worksheets

None

Reference Materials

Figure 6
Figure 7
Figure 8

Key Terms:

Tread
Tread Depth

Objective:

Students will determine the tread depth of a tire using a U.S. penny and quarter.

Activity Overview:

In this activity you will teach your students how to measure the approximate tread depth of the three tire samples using coins. You will also discuss with them the need for tread and how various tread depths affect the performance of the vehicle.

Activity:

To begin, divide the students into three groups, one for each tire. Have each group of students measure each tire with the two coins then pass the tire on to the next group.

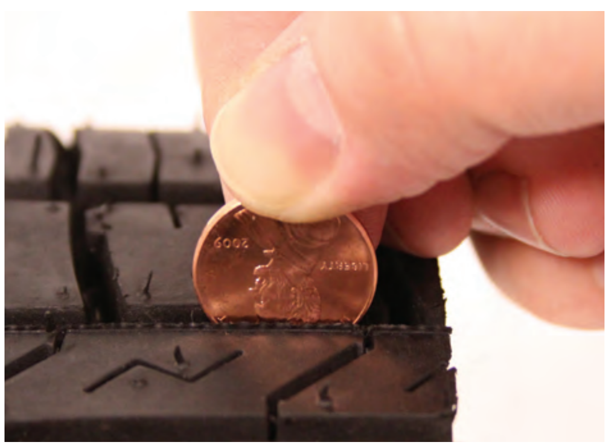

Fig. 6 Penny (head) tread measurement

1. Place a penny into several tread grooves with Lincoln's head toward the tire. If the tire tread covers any portion of Lincoln's head, there is more than 2/32 inch of tread depth remaining on the tire. This is the minimum legal tread depth in the United States.

Fig. 7 Quarter (head) tread measurement

2. **Place a quarter into several tread grooves with Washington's head towards the tire. If the tire tread covers any portion of Washington's head, there is more than 4/32 inch of tread depth remaining on the tire.**

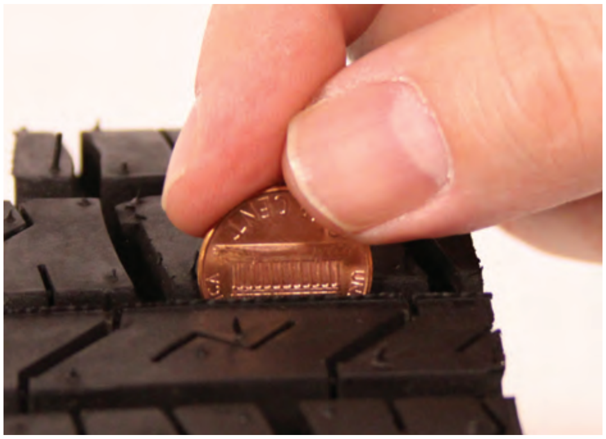

Fig. 8 Penny (tails) tread measurement

3. **Place a penny into several tread grooves with the top of the Lincoln Memorial towards the tire. If the tire tread covers any portion of the Lincoln Memorial, there is more than 6/32 of an inch of tread depth remaining on the tire.**

Discussion Points:

1. **What is the difference between the tread depths for each of the three different tires?**

   It should have been discovered that the bicycle tire has the least amount of tread, with the truck tire having the most. The primary purpose of the grooves in the tread is to allow contaminates such as rain or snow to be removed, so that the rest of the tread can contact the surface. Generally speaking, the deeper the grooves, the more contaminates can be removed. As the bicycle is the slowest vehicle, it needs to remove less water in any given moment than a truck tire. For safety reasons however, the shuttle is not permitted to land while it is raining.

2. Why is the tread depth important to a tire's performance, traction, noise and comfort?

The primary purpose of the grooves in the tread are to remove contaminates from the road. However, the design of the tread plays an important part in many other aspects. While a deep groove provides better traction in the rain, or off-road, it also greatly increases the noise from the tire as the rubber has to be stiffer. Smaller grooves, or groove-less tires (slicks), provide incredible traction on dry pavements which is why they are used on race cars, but would perform horribly when the road was even slightly wet.

NATIONAL SCIENCE STANDARDS 5-8

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PHYSICAL SCIENCE

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PROCESS

- Problem Solving
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Activity 3 Parking Lot Research

GRADES 5-12

Time Requirements: 45 minutes

Materials:

Cars and other vehicles in a parking lot

Worksheets

Vehicle Data Sheet (Worksheet 2)

Reference Materials

Figure 1

Key Terms:

Sidewall
Load Index

Objective:

After reviewing Tire Basics, students will identify the information stamped on the sidewalls of tires found on vehicles in a parking lot.

Activity Overview:

In this activity, students will compare the sidewall designations of tires found on several passenger vehicles. The data collected in this activity can be used in Activity 4, Tire Math if desired. Prior to beginning the lesson, review your facility's safety procedures with the students.

Activity:

The information on a vehicle's tire can explain a lot about the vehicle. Begin this activity by reviewing the Tire Basics section of this lesson with your students to ensure they are familiar with how to read a tire's sidewall information.

1. Divide the class into teams.

Divide students into groups of 3-5 to perform their parking lot research. Make sure there are multiple vehicles in the parking lot to use as research subjects.

Img. 2 Tire Sidewall

2. **Using the Vehicle Data Worksheet, have each team collect the Vehicle Type, Make, Model and Sidewall Numbers from several vehicles.**
   In case a parking lot is not available, or there are an insufficient number of vehicles, you can use the sample data provided on the Vehicle Data Worksheet.

Discussion Points:

1. **Discuss what each of the sidewall numbers means, using one of the collected datasets as an example.**

   You can use the Tire sidewall designation (Fig. 1) as well if required to assist in the review.

2. **Is there any correlation to the specifications of the tire compared to the size of vehicle?**

   It should be noticed that in general, larger tires are used on larger vehicles. Also, trucks will typically have deeper treads than passenger cars of the same size, as trucks need additional traction when working off-road.

3. **Did any of the vehicles have the same tire dimensions?**

4. **What are the dangers of not having the same size and rating on all four tires of a vehicle?**

   With limited exceptions such as race cars, it is vital that a vehicle have identical tires. The following is a list of problems that may be experienced by not having properly matching tires:
   - *Difficulty steering or cornering*
   - *Vehicle may skid frequently, or experience a loss of traction*
   - *Tires are more likely to wear at different rates, which could cause one to explosively fail while in motion*
   - *Fuel economy may be reduced*

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Activity 4 Tire Math

GRADES 5-12

Time Requirements: 45 minutes

Materials:

Worksheets

Vehicle Data Sheet (Worksheet 2)
Tire Math (Worksheet 3)

Reference Materials

Figure 1

Key Terms:

Sidewall

Objective:

Students will use mathematical formulas to determine the diameter and circumference of a tire, as well as the number of revolutions made over a given distance.

Activity Overview:

In this activity, students will use the information found on a tire's sidewall as a basis to calculate additional information. This activity can be done individually, or using the same groups as in Activity 3, Parking Lot Research. This lesson can reinforce concepts learned in math class (such as percentages, conversion factors and using formulas) as well as give students a tangible example of where they might apply some of the concepts they are learning.

If the students have already completed Activity 3, Parking Lot Research, use the same worksheets and their recorded data for this activity. If not, sample data is provided on the Vehicle Data Worksheet.

Depending on skill level, have students work through each problem on the worksheet, or work through them together as a group. Note: the work for each calculation is shown below.

Activity:

Calculate additional information from a tire's sidewall designation.

1. Tire Diameter: Using the example of P225/65R17 92H from Fig. 1 in **Tire Basics**, determine the diameter of the tire.

a. **Convert the tire's width to inches**
There are 25.4 mm in an inch. Divide the width of the tire (225mm) by 25.4 mm/inch to find the width in inches.

$$\frac{225\text{ mm}}{\frac{25.4\text{ mm}}{1\text{ inch}}} = \frac{225\text{ mm}}{1} \cdot \frac{1\text{ inch}}{25.4\text{ mm}} = 8.86\text{ inches}$$

b. **Determine sidewall height of the tire.**
Multiply the width of the tire in inches (8.86 inches) by the aspect ratio (.65 or 65%).

$$8.86 \text{ inches} \cdot 0.65 = 5.76 \text{ inches}$$

c. **Determine the diameter of the tire.**
Add the two sidewall heights and the wheel diameter.

$$5.76 \text{ inches} + 5.76 \text{ inches} + 17 \text{ inches} = 28.52 \text{ inches}$$

d. **Determine the diameter of the other tires on the Vehicle Data Worksheet.**

2. Tire Circumference: The circumference is the distance around the outside edge of a circle. Using P225/65R17 92H and the diameter calculated in #1 determine the circumference of this tire.

pi = π = 3.141592, C = circumference, D = diameter, r = radius

$$C = 2\pi r \quad \text{or} \quad C = \pi D$$

a. **Use the formula for the circumference of a circle to find the circumference of the tire.**

$$\pi \cdot 28.53 \text{ inches} = 89.63 \text{ inches}$$

b. **The Space Shuttle tire has a diameter of 44.9 inches; what is its circumference?**

$$\pi \cdot 44.9 \text{ inches} = 141 \text{ inches}$$

c. **Determine the circumference of the other tires on the Vehicle Data Worksheet.**

3. Tire Revolutions: Determine the speed and revolutions of the Space Shuttle tires during a landing.

When the first Space Shuttle, Columbia, landed at Edwards Air Force Base on April 14, 1981, it was traveling at 353 km/hr (190 kts/219 mph) and traveled 8,993 feet before coming to a complete stop.

a. **Determine the tire's speed during touchdown in inches per second.**
Convert miles per hour (mph) into inches per hour.
Multiply miles per hour (219) by the number of feet in a mile (5,280) and the number of inches in a foot (12).

$$\frac{219 \text{ miles}}{1 \text{ hour}} \cdot \frac{5{,}280 \text{ feet}}{1 \text{ mile}} \cdot \frac{12 \text{ inches}}{1 \text{ foot}} = 13{,}875{,}840 \text{ inches/hours}$$

Determine the number of seconds in an hour.
Multiply the number of minutes in an hour (60) by the number of seconds in a minute (60).

$$\frac{60 \text{ minutes}}{1 \text{ hour}} \cdot \frac{60 \text{ seconds}}{1 \text{ minute}} = 3600 \text{ seconds/hour}$$

Convert inches per hour into inches per second.

$$\frac{\frac{13{,}875{,}840 \text{ inches}}{1 \text{ hour}}}{\frac{3600 \text{ seconds}}{1 \text{ hour}}} = \frac{13{,}875{,}840 \text{ inches}}{1 \text{ hour}} \cdot \frac{1 \text{ hour}}{3600 \text{ seconds}} = 3{,}854.4 \text{ inches/seconds}$$

b. Calculate the rotational speed of the wheel in revolutions per minute.

Revolutions per second: Divide the number of inches traveled per second (3,854.4) by the tire's circumference (141 inches) to calculate the number of revolutions the tire made each second.

$$\frac{\frac{3{,}854.4 \text{ inches}}{1 \text{ seconds}}}{141 \text{ inches}} = \frac{3{,}854.4 \text{ inches}}{1 \text{ seconds}} \cdot \frac{1}{141 \text{ inches}} = 27.3 \text{ revolutions/second}$$

Revolutions per minute: Multiply the number of revolutions per second the tires made (27.3) by the number of seconds per minute (60).

$$\frac{27.3 \text{ revolutions}}{1 \text{ second}} \cdot \frac{60 \text{ seconds}}{1 \text{ minute}} = 1{,}638 \text{ revolutions/minute}$$

c. Calculate the number of revolutions the tires made while traveling the entire stopping distance.

Convert feet into inches.

Multiply the number of feet traveled (8,993) by the number of inches in a foot (12).

$$\frac{8{,}993 \text{ feet}}{8{,}993 \text{ feet}} \cdot \frac{12 \text{ inches}}{1 \text{ foot}} = 107{,}916 \text{ inches}$$

Divide inches traveled (107,916) by the tire's circumference (141 inches) to determine the total number of revolutions the tire made.

$$\frac{107{,}916 \text{ inches}}{141 \text{ inches}} = 765.36 \text{ revolutions}$$

d. Determine how many revolutions the other tires from the Vehicle Data Worksheet would make if they traveled 30,000 miles.

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Activity 5 Tire Air Pressure

GRADES 5-12

Materials:

Worksheets

Tire Air Pressure (Worksheet 4)

Reference Materials

None

Key Terms:

PSI (Pounds per Square Inch)

Time Requirements: 30 minutes

Objective:

Students will explore how tire pressure can impact the life of a tire along with its effects on fuel efficiency.

Activity Overview:

Having properly inflated tires is not only necessary for safety but also helps in increasing a vehicle's fuel efficiency. Before beginning with the lessons below, discuss with the students the causes for air pressure loss. In addition to the usual culprits of leaks and punctures, temperature changes can also cause pressure loss especially during the winter months. This is due to the air molecules being closer together at lower temperatures.

Worksheets are included for the students to use when making the calculations below.

Activity:

1. Tire Life: The expected mileage of a tire decreases by approximately 1% for every 1% the tire is under-inflated. If your tires were supposed to be inflated to 32 psi, and you drove the last 4,000 miles with your tires inflated to 29 psi, how many miles did you lose from each tire's life?

a. Determine the percentage of under-inflation.
Divide the actual air pressure measurement by the recommended air pressure measurement, then subtract from 100 to give the final answer.

$$\frac{\frac{29\text{ pounds}}{1\text{ inch}^2}}{\frac{32\text{ pounds}}{1\text{ inch}^2}} = \frac{29\text{ pounds}}{1\text{ inch}^2} \cdot \frac{1\text{ inch}^2}{32\text{ pounds}} = 90.6\%$$

$$100\% - 90.6\% = 9.4\%$$

b. Determine mileage lost due to under inflation.
Multiply the distance driven (4,000 miles) by the percentage of under inflation (9.4%) to calculate the number of miles lost from the tire's overall life.

$$4000 \text{ miles} \cdot 0.094 = 376 \text{ miles}$$

2. Convert the numbers of miles lost over the life of the tire in #1 to kilometers. (1 mile = 1.61 kilometers)

$$376 \text{ miles} \cdot \frac{1.61 \text{ km}}{1 \text{ mile}} = 605.36 \text{ km}$$

3. Tire Temperature: Tires lose 1 psi for every 10˚F (5.56˚C) drop in temperature. If you travel from Phoenix (90˚F) to Cleveland (30˚F) and do not adjust your tire pressure, how much air pressure will your tires lose from the temperature change?

a. Determine the decrease in temperature.

$$90^\circ\text{F} - 30^\circ\text{F} = 60\ \text{F}^\circ$$

b. To determine how much air pressure is lost, multiply the temperature difference by the ratio of air pressure loss (1 psi per 10F˚).

$$60\ \text{F}^\circ \cdot \frac{1 \text{ psi}}{10\ \text{F}^\circ} = 6 \text{ psi}$$

4. Gas Mileage: If your car gets 20 miles/gallon and you drive 1,000 miles with your tires under-inflated by 6 psi, how much extra fuel will you need? For this example, assume that if a tire is under-inflated by 6 psi, it will decrease gas mileage by 3%.

a. Determine the amount of fuel needed under ideal conditions.
Divide mileage driven by miles/gallon.

$$\frac{1000 \text{ miles}}{\frac{20 \text{ miles}}{1 \text{ gallon}}} = \frac{1000 \text{ miles}}{1} \cdot \frac{1 \text{ gallon}}{20 \text{ miles}} = 50 \text{ gallons}$$

b. Determine the percentage of inefficiency.

$$100\% - 3\% = 97\%\ (0.97)$$

c. Determine the number of additional miles traveled due to inefficiency.
Divide the total mileage potential by the inefficiency percentage.

$$\frac{1000 \text{ miles}}{0.97} = 1030.90 \text{ miles}$$

d. Determine how many miles were lost due to under inflation.
Subtract the mileage achieved (1,000 miles) from the total mileage potential.

$$1030.90 \text{ miles} - 1000 \text{ miles} = 30.90 \text{ miles lost due to under-inflation}$$

e. **Determine the additional number of gallons needed to drive 1000 miles on under-inflated tires.**

$$\frac{1030.90 \text{ miles}}{\frac{20 \text{ miles}}{1 \text{ gallon}}} = \frac{1030.90 \text{ miles}}{1} \cdot \frac{1 \text{ gallon}}{20 \text{ miles}} = 51.50 \text{ gallons}$$

51.50 gallons - 50 gallons = 1.5 gallons of extra fuel needed for this trip

5. Assume gas costs $3.00 per gallon. Determine how much extra you would pay to drive 1,000 miles on the under-inflated tires in #4.

1.5 gallons • $3.00 = $4.50

Discussion:

1. **Why do tires lose air pressure?**
   The primary causes are punctures, leaks and temperature changes (any quantity of gas contained to a fixed volume will increase in pressure with an increase in temperature, and will decrease in pressure with any decrease in temperature) although rubber tires are porous and will naturally lose air over time).

2. **How can a change in temperature affect your car's fuel efficiency?**
   A drop in temperature can cause the tires' air pressure to drop. A decreased air pressure results in decreased fuel efficiency.

3. **Why is it important for a tire to be properly inflated?**
   An improperly inflated tire will cause vehicle handling issues which may lead to a crash. It also increases fuel consumption and reduces the life of the tire.

4. **An over inflated tire causes less area of the tire to contact the road (the contact patch). How would this effect handling?**
   An over-inflated tire reduces the amount of rubber in contact with the road at any one time. As such, the tire is not able to grip the road properly which may cause the vehicle to slide while turning.

5. **Research the consequences of under inflated tires (Fig. 9).**
   An under-inflated tire prevents the center of the tire tread from touching the road and instead runs on the tread edges. This greatly reduces the life of the tire and its ability to grip the road. It also causes much more road noise.

Fig. 9 Tire inflation

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

PHYSICAL SCIENCE

• Properties and changes of properties in matter

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

PHYSICAL SCIENCE

• Structure and properties of matter
• Interactions of energy and matter

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

NATIONAL MATH STANDARDS K-12

NUMBER AND OPERATIONS

• Understand numbers, ways of representing numbers, relationships among numbers, and number systems

• Understand meanings of operations and how they relate to one another

• Compute fluently and make reasonable estimates

ALGEBRA

• Represent and analyze mathematical situations and structures using algebraic symbols

• Use mathematical models to represent and understand quantitative relationships

MEASUREMENT

• Understand measurable attributes of objects and the units, systems, and processes of measurement

• Apply appropriate techniques, tools, and formulas to determine measurements.

DATA ANALYSIS AND PROBABILITY

• Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

• Problem Solving

• Communication

• Connections

• Representation

Reference Materials

Fig. 1 Tire sidewall designation

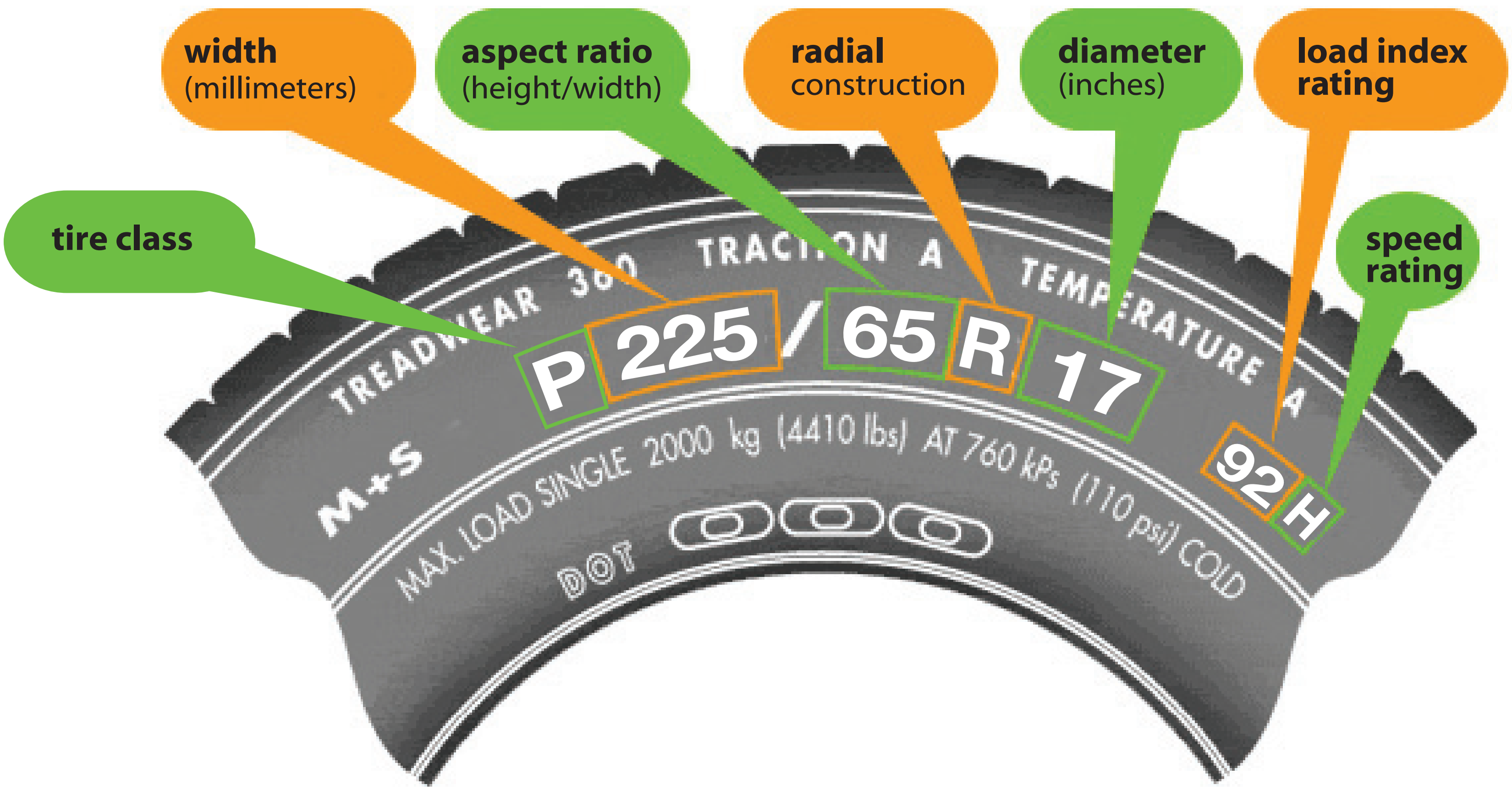


Fig. 2 Tire cross section

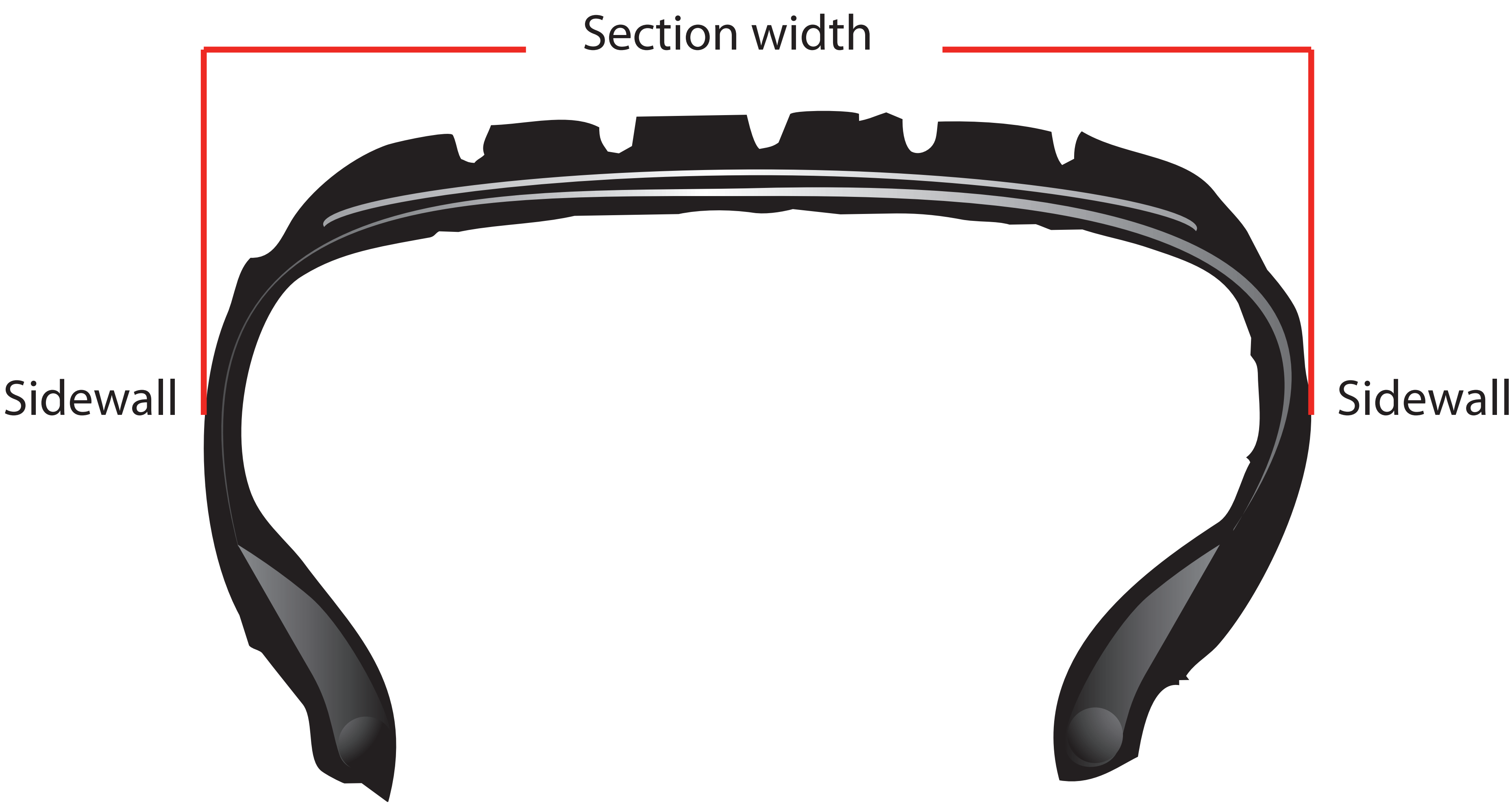
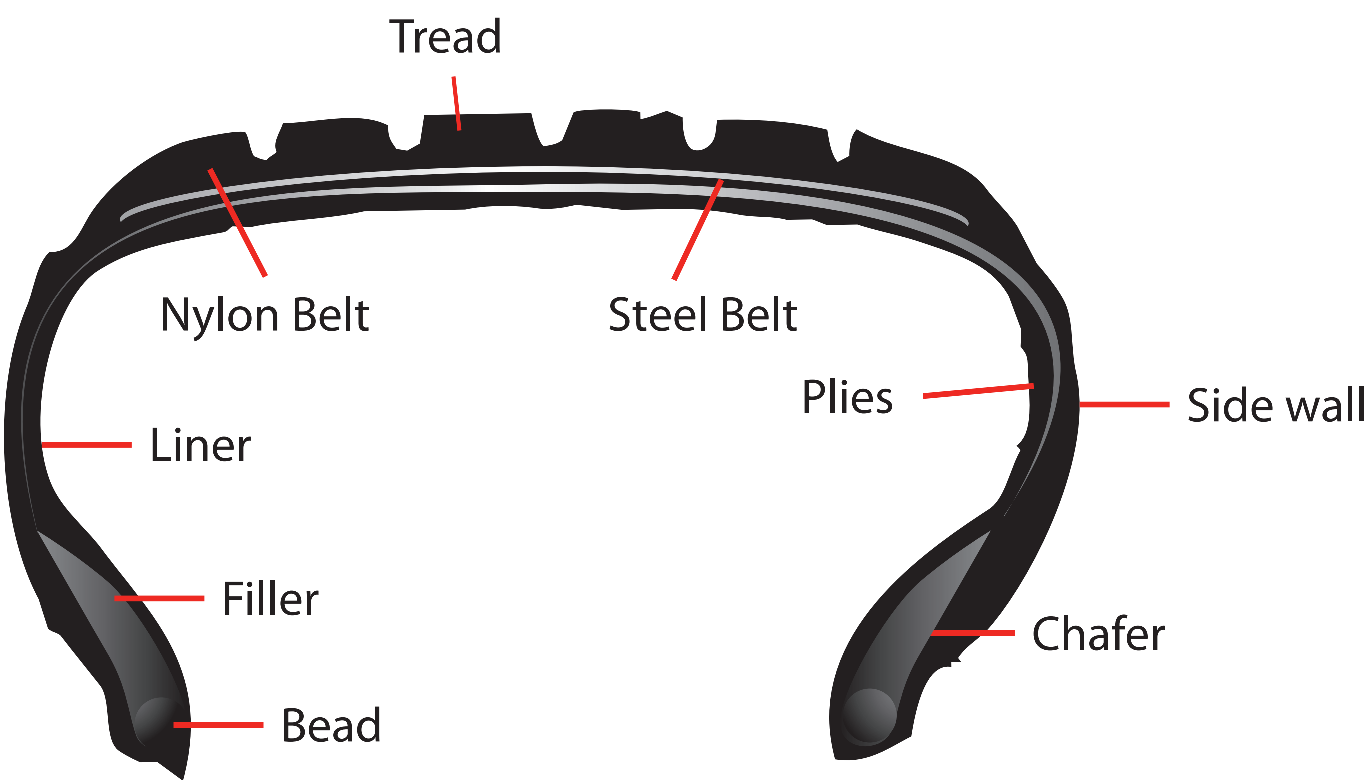


Fig. 3 Tire with cross section

Fig. 4 Parts of a tire



Bead
A high-strength steel wire and rubber that hold the plies and the tire assembly onto the rim of the wheel.

Belt (Nylon and Steel Belts)
Narrow layer of coated tire cord or rubber-encased steel cord located directly under the tire tread that are designed to resist deformation.

Chafer
A layer of rubber compound that is applied to the bead; the chafer provides protection against rim chafing and other external damage.

Filler
A rubber compound that smoothly fits the plies to the bead.

Liner
A thin layer of rubber inside the tire which contains compressed air. Some tires use a tube in place of the liner.

Plies
Layers of fabric cord extending from bead to bead that reinforce the tire.

Sidewall
The part of the tire between the bead and the tread.

Tread
The most recognizable part of the tire. It is composed of wear-resistant rubber compound that provides traction and assists in removing road surface water and contaminants.

Fig. 5 Venn Diagram

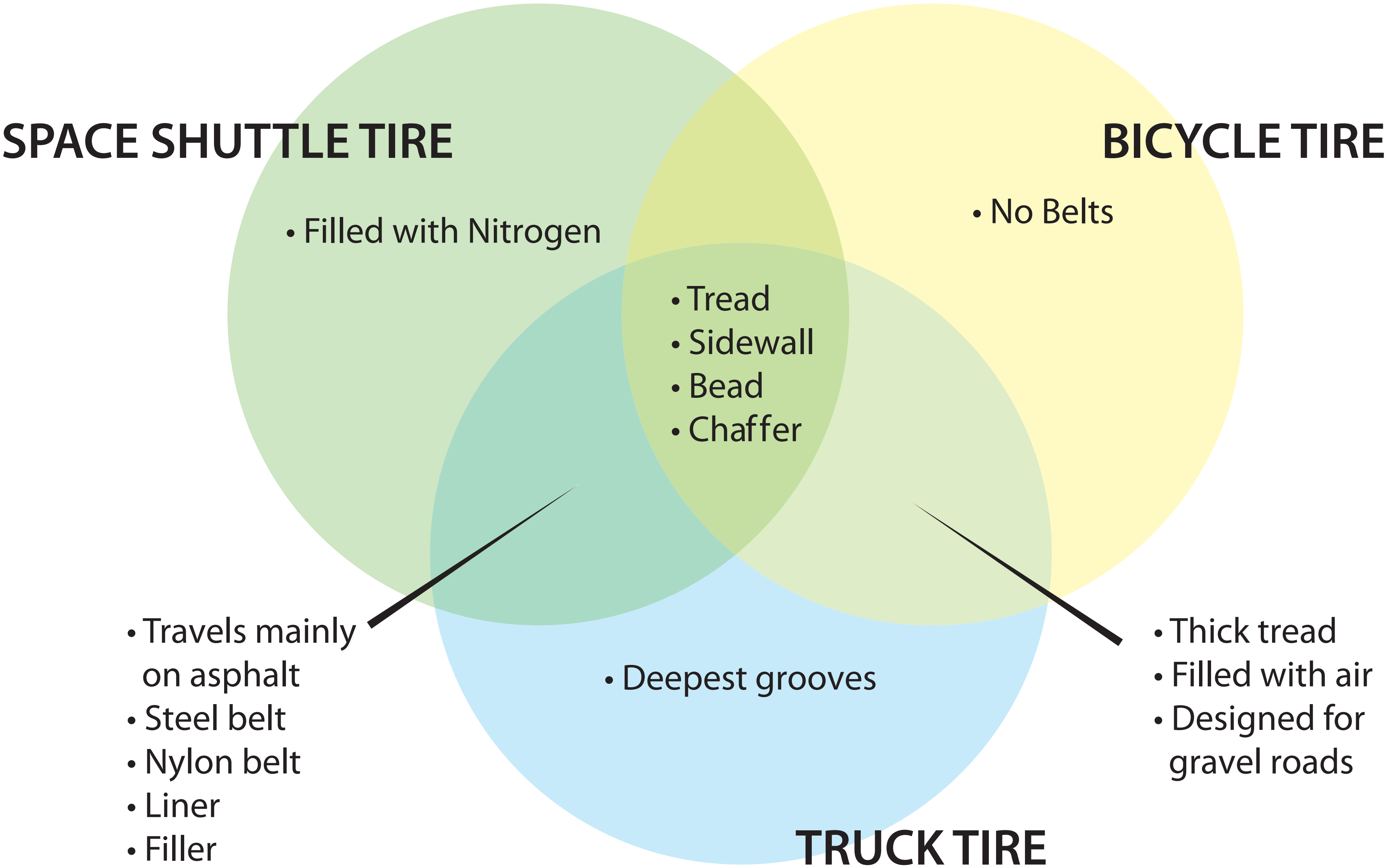


Fig. 6 **Penny (head) tread measurement**

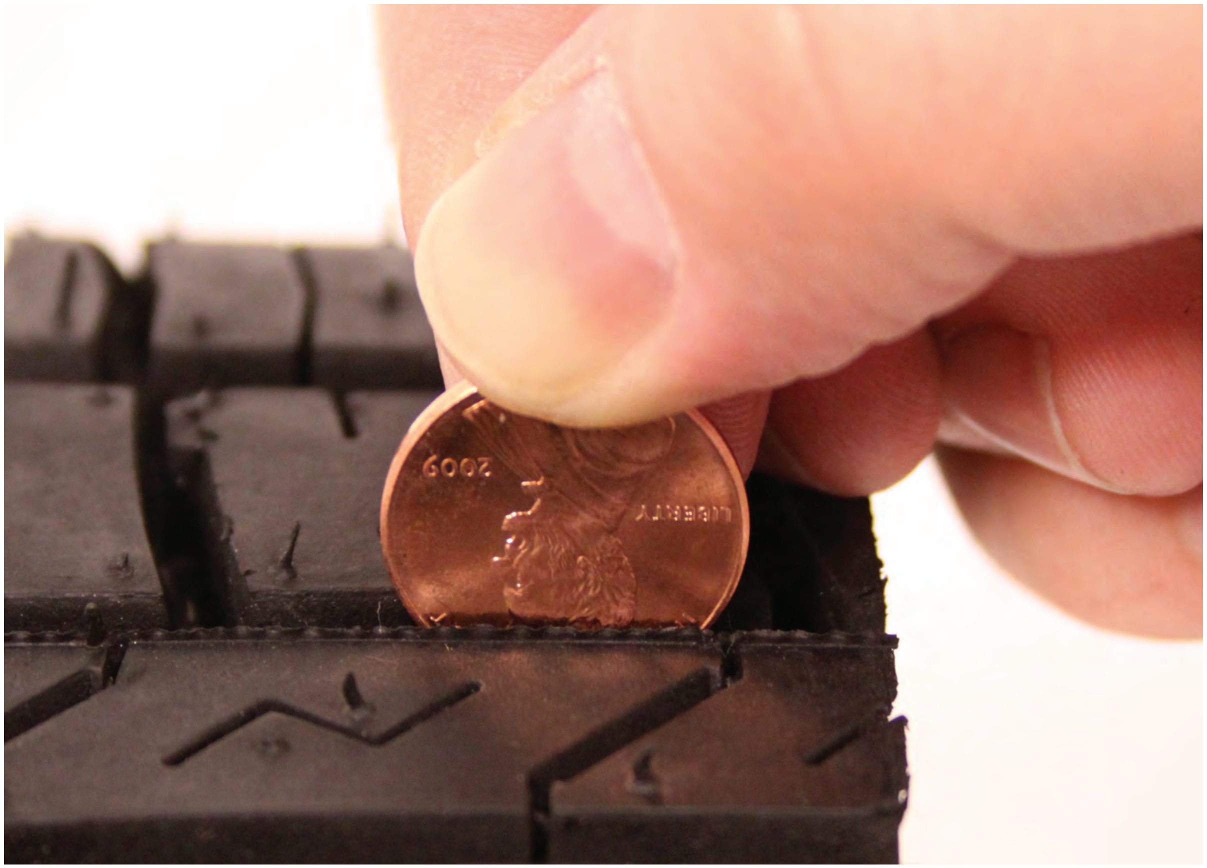


Fig. 7 **Quarter (head) tread measurement**

Fig. 8 Penny (tails) tread measurement

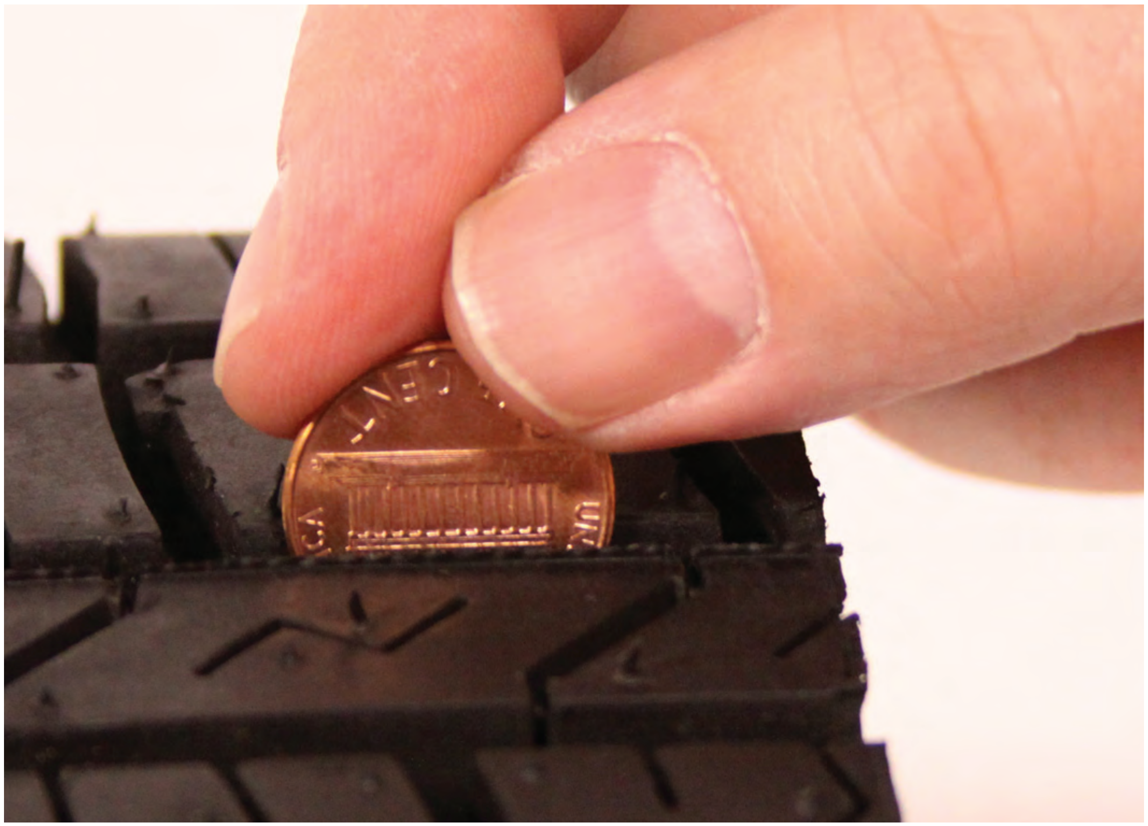


Fig. 9 Tire inflation

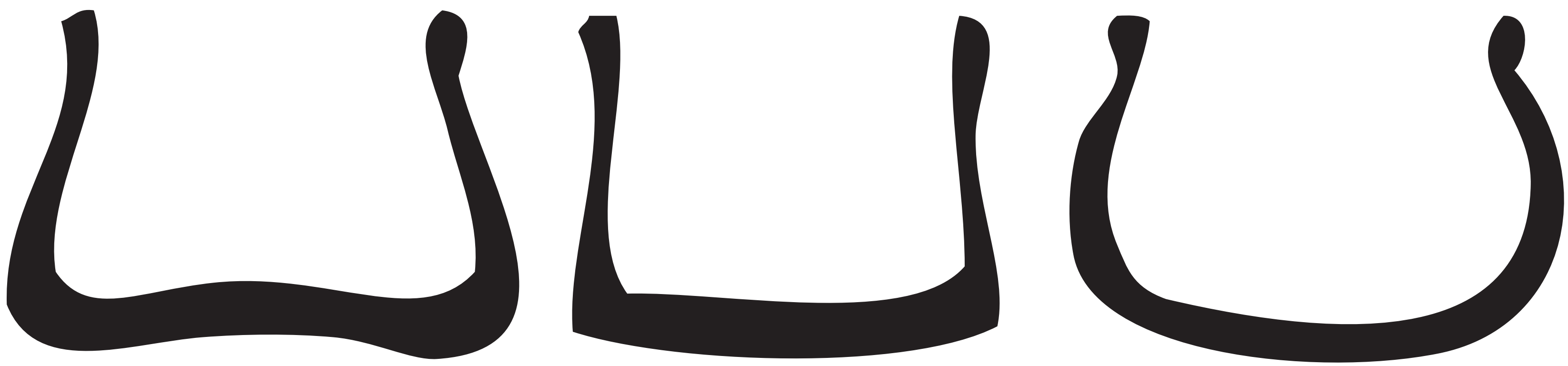


Fig. 10 Load Index Table

The load index refers to the load-carrying capacity of a tire, or how much weight a tire can support. For example, if a tire has a load index of 82, it can support 1,047 pounds at maximum air pressure. Multiply that by four (4 x 1,047 = 4,188 pounds) to get your maximum load-carrying capacity. It is not recommended to install tires with a lower load-carrying capacity than what came on your car from the factory

Load Index	Load (lbs)	Load Index	Load (lbs)	Load Index	Load (lbs)	Load Index	Load (lbs)	Load Index	Load (lbs)	Load Index	Load (lbs)
0	99	25	204	50	419	75	852	100	1764	125	3638
1	102	26	209	51	130	76	882	101	1819	126	3748
2	105	27	215	52	441	77	908	102	1874	127	3858
3	107	28	220	53	454	78	937	103	1929	128	3968
4	110	29	227	54	467	79	963	104	1984	129	4079
5	114	30	234	55	481	80	992	105	2039	130	4189
6	117	31	240	56	494	81	1019	106	2094	131	4289
7	120	32	247	57	507	82	1047	107	2149	132	4409
8	123	33	254	58	520	83	1074	108	2205	133	4541
9	128	34	260	59	536	84	1102	109	2271	134	4674
10	132	35	267	60	551	85	1135	110	2337	135	4806
11	136	36	276	61	567	86	1168	111	2403	136	4938
12	139	37	282	62	584	87	1201	112	2469	137	5071
13	143	38	291	63	600	88	1235	113	2535	138	5203
14	148	39	300	64	617	89	1279	114	2601	139	5357
15	152	40	309	65	639	90	1323	115	2679	140	5512
16	157	41	309	66	639	91	1356	116	2756	141	5677
17	161	42	331	67	677	92	1389	117	2833	142	5842
18	165	43	342	68	694	93	1433	118	2910	143	6008
19	171	44	353	69	716	94	1477	119	2998	144	6173
20	176	45	364	70	739	95	1521	120	3086	145	6393
21	182	46	397	71	761	96	1565	121	3197	146	6614
22	187	47	386	72	783	97	1609	122	3307	147	6779
23	193	48	397	73	805	98	1653	123	3417	148	6844
24	198	49	408	74	827	99	1709	124	3527	149	7385

Glossary

Bead:
A high-strength steel wire and rubber that hold the plies and the tire assembly onto the rim of the wheel.

Belt:
Narrow layer of coated tire cord or rubber-encased steel cord located directly under the tire tread that are designed to resist deformation.

Chafer:
A layer of rubber compound that is applied to the bead; the chafer provides protection against rim chafing and other external damage.

Filler:
A rubber compound that smoothly fits the plies to the bead.

Liner:
A thin layer of rubber inside the tire which contains compressed air. Some tires use a tube in place of the liner.

Load Index:
The maximum load each tire can carry.

PSI:
Pounds per Square Inch; one psi is one pound of force applied to one square inch of surface material.

Plies:
Layers of fabric cord extending from bead to bead that reinforce the tire.

Sidewall:
The part of the tire between the bead and the tread.

Tread:
The most recognizable part of the tire. It is composed of wear-resistant rubber compound that provides traction and assists in removing road surface water and contaminants.

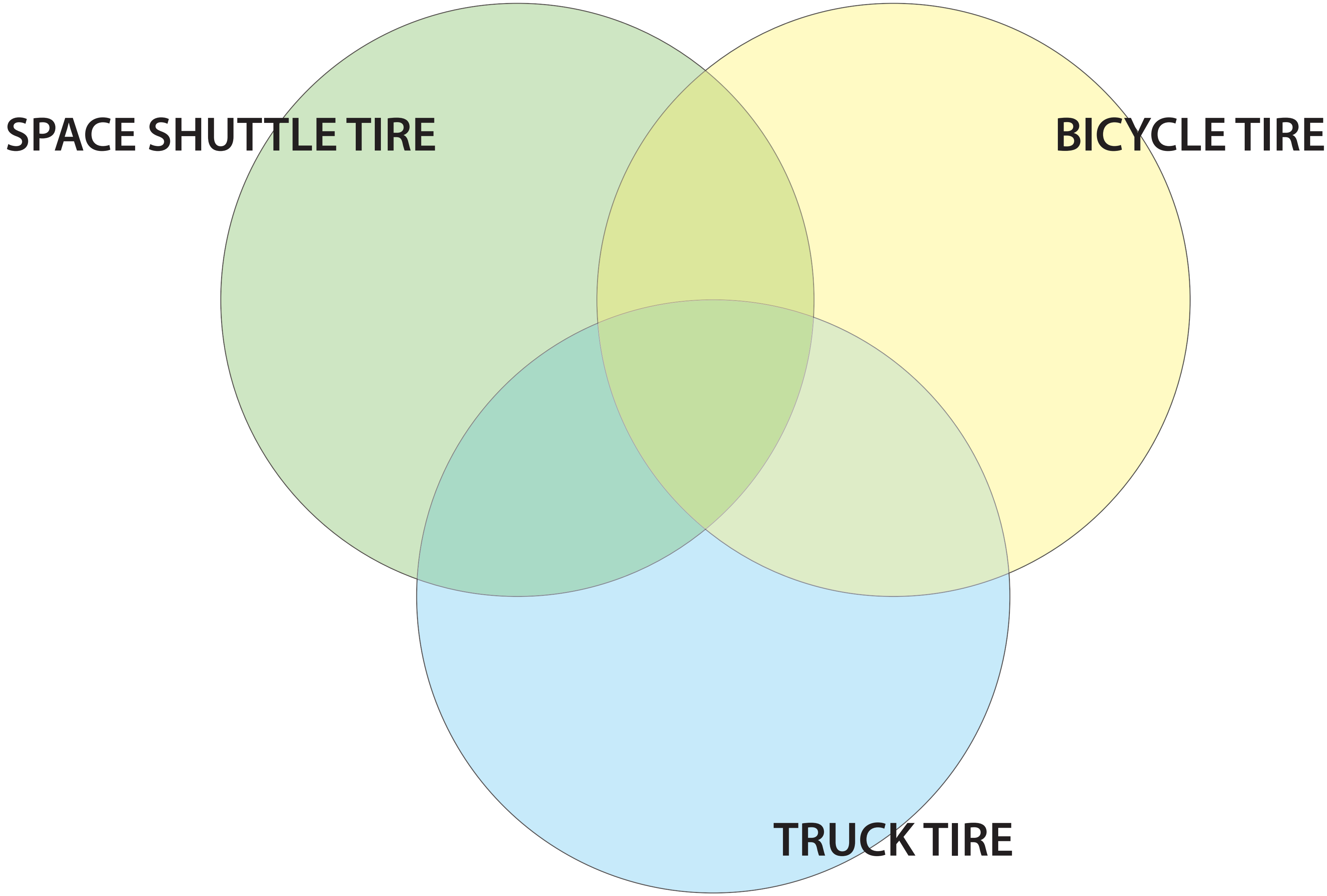
Tire Class:
The group or category to which the tire belongs (ex: P=Passenger, LT=light truck).

Tread Depth:
The distance from the top of the tread to the bottom of the grooves.

Tread Life:
The number of miles the tread on a tire is expected to last.

Student Worksheets

Worksheet 1 Venn Diagram



Worksheet 2 Vehicle Data

Vehicle Type	Make	Model	Sidewall Numbers	Diameter	Circumference	Revolutions in 30,000 miles
Car	Dodge	Neon	185/60R15			
Car	Toyota	Matrix	205/55R16			
Truck	Ford	F150	255/65R17			
Truck	Nissan	Titan	285/70/R17			
SUV	Honda	CRV	205/70R15			

FORMULAS

Tire Circumference:

$C = 2\pi r$ or $C = \pi D$

$$\text{\% Under Inflation} = 100\% - \frac{\text{Actual Air Pressure}}{\text{Recommended Air Pressure}}$$

$$\text{Revolutions} = \frac{\text{Distance Traveled}}{\text{Circumference}}$$

CONVERSIONS

1 inch = 25.4 mm

1 mile = 1.61 km

5,280 ft = 1 mile

12 inches = 1 foot

π = 3.141592

Worksheet 3 Tire Math

1. Tire Diameter: Using the example of P225/65R17 92H from Figure 1 in **Tire Basics**, determine the diameter of the tire.

a. Convert the tire's width to inches

There are 25.4 mm in an inch. Divide the width of the tire by 25.4 mm/inch to find the width in inches.

$$\frac{225\text{ mm}}{\frac{25.4\text{ mm}}{1\text{ inch}}} = \frac{225\text{ mm}}{1} \cdot \frac{1\text{ inch}}{25.4\text{ mm}} = 8.86\text{ inches}$$

b. Determine sidewall height of the tire.

Multiply the width of the tire in inches by the aspect ratio (.65 or 65%).

8.86 inches • 0.65 = 5.76 inches

c. Determine the diameter of the tire.

Add the two sidewall heights and the wheel diameter.

5.76 inches + 5.76 inches + 17 inches = 28.52 inches

d. Determine the diameter of the other tires on the Vehicle Data Worksheet.

MUSEUM IN A BOX

Worksheet 3 Continued

2. Tire Circumference: The circumference is the distance around the outside edge of a circle. Using P225/65R17 92H and the diameter calculated in #1 determine the circumference of this tire.

pi = π = 3.141592, C = circumference, D = diameter, r = radius

$C = 2\pi r$ or $C = \pi D$

a. **Use the formula for the circumference of a circle to find the circumference of the tire.**

b. **The Space Shuttle tire has a diameter of 44.9 inches; what is its circumference?**

c. **Determine the circumference of the other tires on the Vehicle Data Worksheet.**

Worksheet 3 Continued

3. Tire Revolutions: Determine the speed and revolutions of the Space Shuttle tires during a landing.

When the first Space Shuttle, Columbia, landed at Edwards Air Force Base on April 14, 1981, it was traveling at 353 km/hr (190 kts/219 mph) and traveled 8,993 feet before coming to a complete stop.

a. Determine the tire's speed during touchdown in inches per second.
Convert miles per hour (mph) into inches per hour.

$$\frac{219 \text{ miles}}{1 \text{ hour}} \cdot \frac{5{,}280 \text{ feet}}{1 \text{ mile}} \cdot \frac{12 \text{ inches}}{1 \text{ foot}} = 13{,}875{,}840 \text{ inches/hours}$$

Determine the number of seconds in an hour.

$$\frac{60 \text{ minutes}}{1 \text{ hour}} \cdot \frac{60 \text{ seconds}}{1 \text{ minute}} = 3600 \text{ seconds/hour}$$

Convert inches per hour into inches per second.

$$\frac{\dfrac{\underline{\qquad} \text{ inches}}{1 \text{ hour}}}{\dfrac{\underline{\qquad} \text{ seconds}}{1 \text{ hour}}} = \frac{\underline{\qquad} \text{ inches}}{1 \text{ hour}} \cdot \frac{1 \text{ hour}}{\underline{\qquad} \text{ seconds}} = \underline{\qquad} \text{ inches/seconds}$$

b. Calculate the rotational speed of the wheel in revolutions per minute.

Revolutions per second: Divide the number of inches traveled per second by the tire's circumference to calculate the number of revolutions the tire made each second.

$$\frac{\dfrac{3{,}854.4 \text{ inches}}{1 \text{ seconds}}}{141 \text{ inches}} = \frac{3{,}854.4 \text{ inches}}{1 \text{ seconds}} \cdot \frac{1}{141 \text{ inches}} = 27.3 \text{ revolutions/second}$$

Revolutions per minute: Multiply the number of revolutions per second the tires made by the number of seconds per minute (60).

$$\frac{27.3 \text{ revolutions}}{1 \text{ second}} \cdot \frac{60 \text{ seconds}}{1 \text{ minute}} = 1{,}638 \text{ revolutions/minute}$$

c. Calculate the number of revolutions the tires made while traveling the entire stopping distance.
Convert feet into inches by multiplying the number of feet traveled by the number of inches in a foot.

$$\frac{8{,}993 \text{ feet}}{8{,}993 \text{ feet}} \cdot \frac{12 \text{ inches}}{1 \text{ foot}} = 107{,}916 \text{ inches}$$

Divide inches traveled by the tire's circumference to determine the total number of revolutions the tire made.

d. Determine how many revolutions the other tires from the Vehicle Data Worksheet would make if they traveled 30,000 miles.

Worksheet 4 Tire Air Pressure

1. Tire Life: The expected mileage of a tire decreases by approximately 1% for every 1% the tire is under-inflated. If your tires were supposed to be inflated to 32 psi, and you drove the last 4,000 miles with your tires inflated to 29 psi, how many miles did you lose from each tire's life?

a. Determine the percentage of under-inflation.

$$\frac{\frac{29 \text{ pounds}}{1 \text{ inch}^2}}{\frac{32 \text{ pounds}}{1 \text{ inch}^2}} = \frac{29 \text{ pounds}}{1 \text{ inch}^2} \bullet \frac{1 \text{ inch}^2}{32 \text{ pounds}} = 90.6\%$$

$$100\% - 90.6\% = 9.4\%$$

b. Determine mileage lost due to under inflation.

2. Convert the numbers of miles lost over the life of the tire in #1 to kilometers. (1 mile = 1.61 kilometers)

3. Tire Temperature: Tires lose 1 psi for every 10˚ F (5.56˚ C) drop in temperature. If you travel from Phoenix (90˚ F) to Cleveland (30˚ F) and do not adjust your tire pressure, how much air pressure will your tires lose from the temperature change?

a. Determine the decrease in temperature.

b. To determine how much air pressure is lost, multiply the temperature difference by the ratio of air pressure loss (1 psi per 10 F˚).

$$60 \text{ F}^\circ \bullet \frac{1 \text{ psi}}{10 \text{ F}^\circ} = 6 \text{ psi}$$

Worksheet 4 Continued

4. Gas Mileage: If your car gets 20 miles/gallon and you drive 1,000 miles with your tires under-inflated by 6 psi, how much extra fuel will you need? For this example, assume that if a tire is under-inflated by 6 psi, it will decrease gas mileage by 3%.

a. **Determine the amount of fuel needed under ideal conditions.**

$$\frac{\underline{\quad\quad}\ \text{miles}}{\dfrac{\underline{\quad\quad}\ \text{miles}}{1\ \text{gallon}}} = \frac{\underline{\quad\quad}\ \text{miles}}{1} \cdot \frac{1\ \text{gallon}}{\underline{\quad\quad}\ \text{miles}} = \underline{\quad\quad}$$

b. **Determine the percentage of inefficiency.**

c. **Determine the number of additional miles travelled due to inefficiency.**
Divide the total mileage potential by the inefficiency percentage.

$$\frac{\underline{\quad\quad}\ \text{miles}}{0.97} = \underline{\quad\quad}\ \text{miles}$$

d. **Determine how many miles were lost due to under inflation.**

e. **Determine the additional number of gallons needed to drive 1000 miles on under-inflated tires.**

$$\frac{\underline{\quad\quad}\ \text{miles}}{\dfrac{20\ \text{miles}}{1\ \text{gallon}}} = \frac{\underline{\quad\quad}\ \text{miles}}{1} \cdot \frac{1\ \text{gallon}}{20\ \text{miles}} = \underline{\quad\quad}\ \text{gallons}$$

1.50 gallons - 50 gallons = 1.5 gallons of extra fuel needed for this trip

5. Assume gas costs $3.00 per gallon. Determine how much extra you would pay to drive 1,000 miles on the under-inflated tires in #4.

Images

Img. 1 Tire Cross Sections

Img. 2 Tire Sidewall

Img. 3 Installing a main shuttle tire

(Photo courtesy of NASA – www.nasaimages.org)

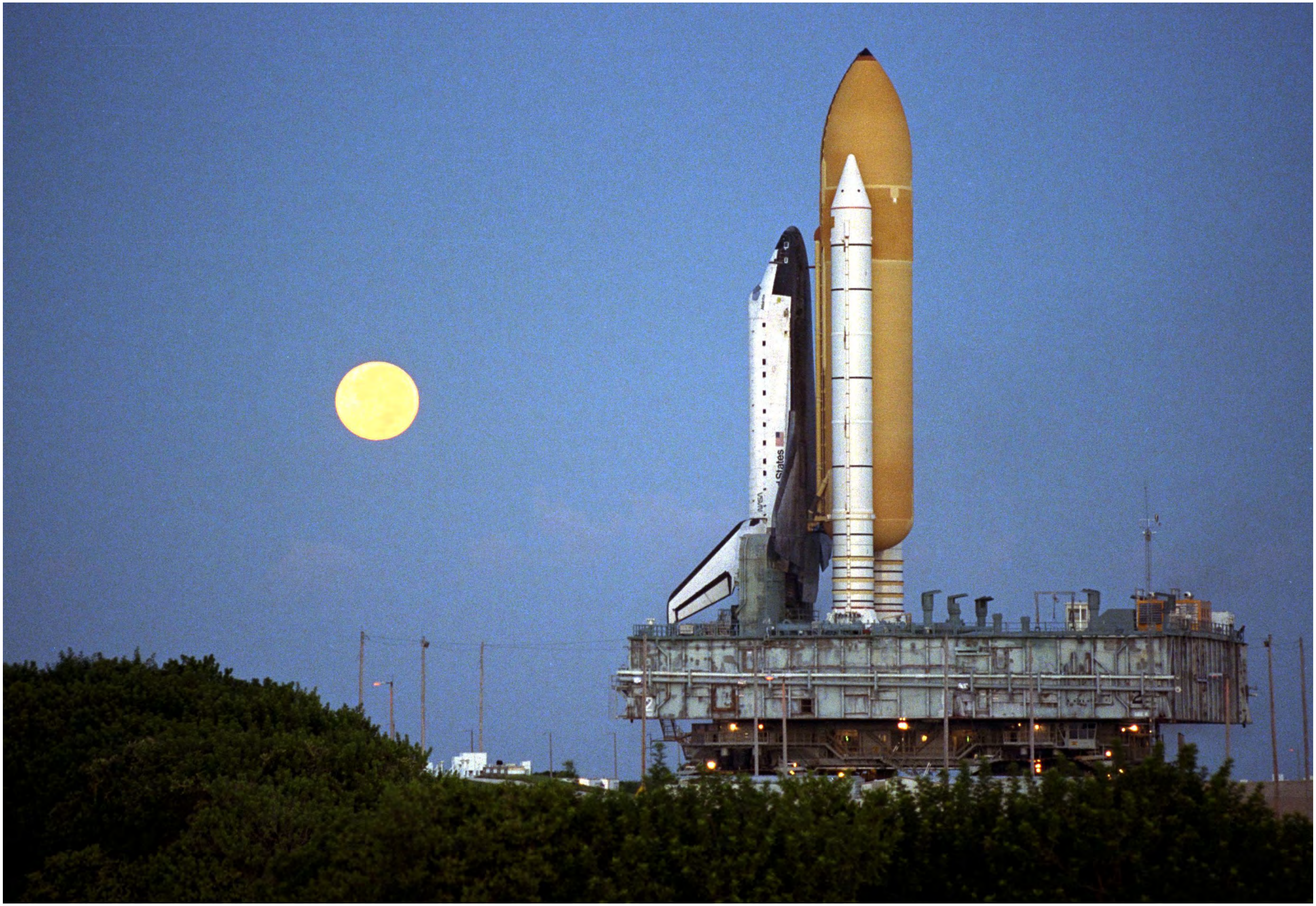
Img. 4 **The Space Shuttle at lift-off**

(Photo courtesy of NASA – www.nasaimages.org)

Img. 5 The Space Shuttle en-route to the launch pad

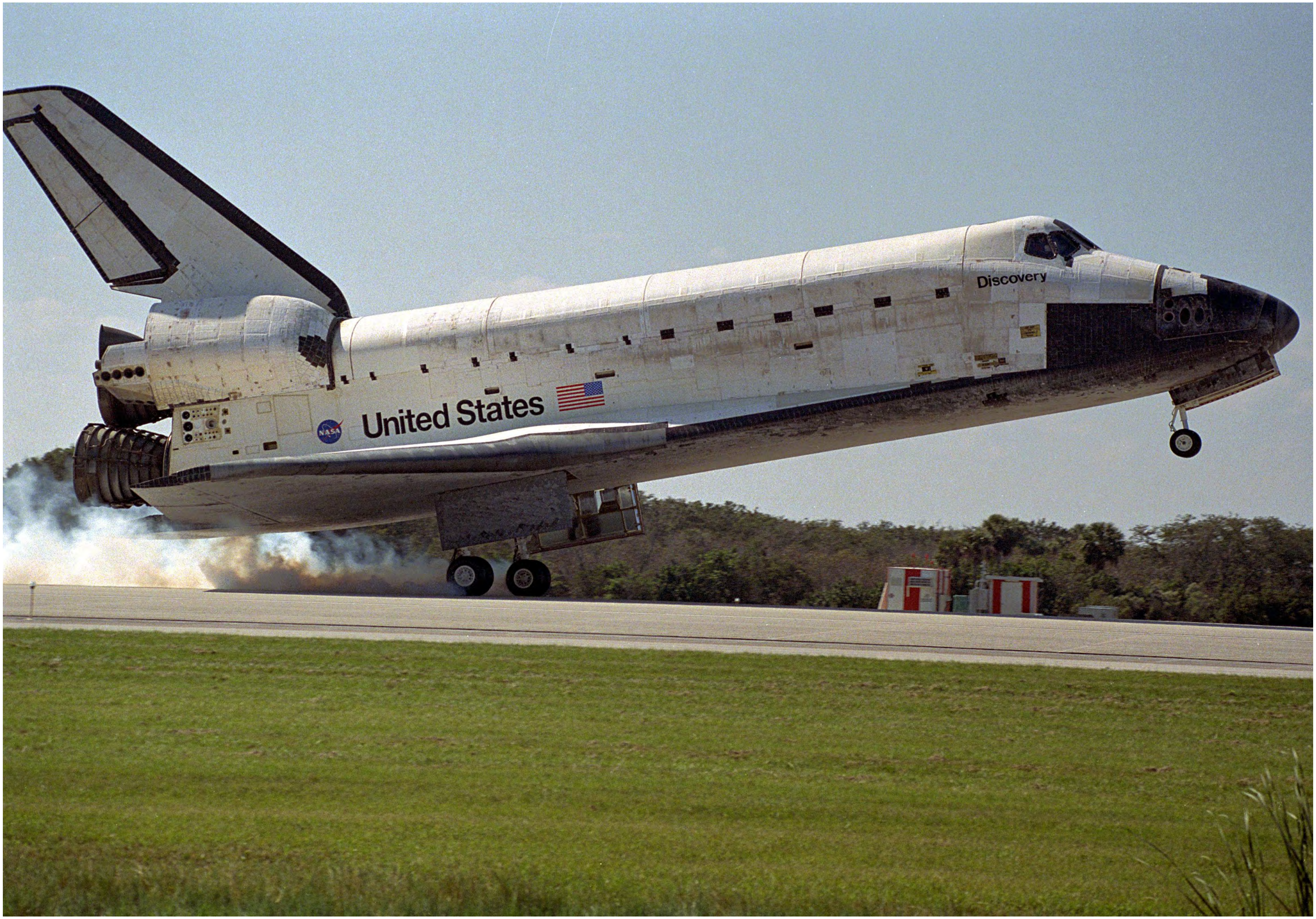
(Photo courtesy of NASA – www.nasaimages.org)

Img. 6 The Space Shuttle on the launch pad



(Photo courtesy of NASA – www.nasaimages.org)

Img. 7 The Shuttle Discovery landing at Kennedy Space Center



(Photo courtesy of NASA – www.nasaimages.org)

Img. 8 The Shuttle Endeavour landing at Kennedy Space Center

(Photo courtesy of NASA – www.nasaimages.org)

Img. 9 The Shuttle Columbia landing at Edwards Air Force Base

(Photo courtesy of NASA – www.nasaimages.org)

Aeronautics
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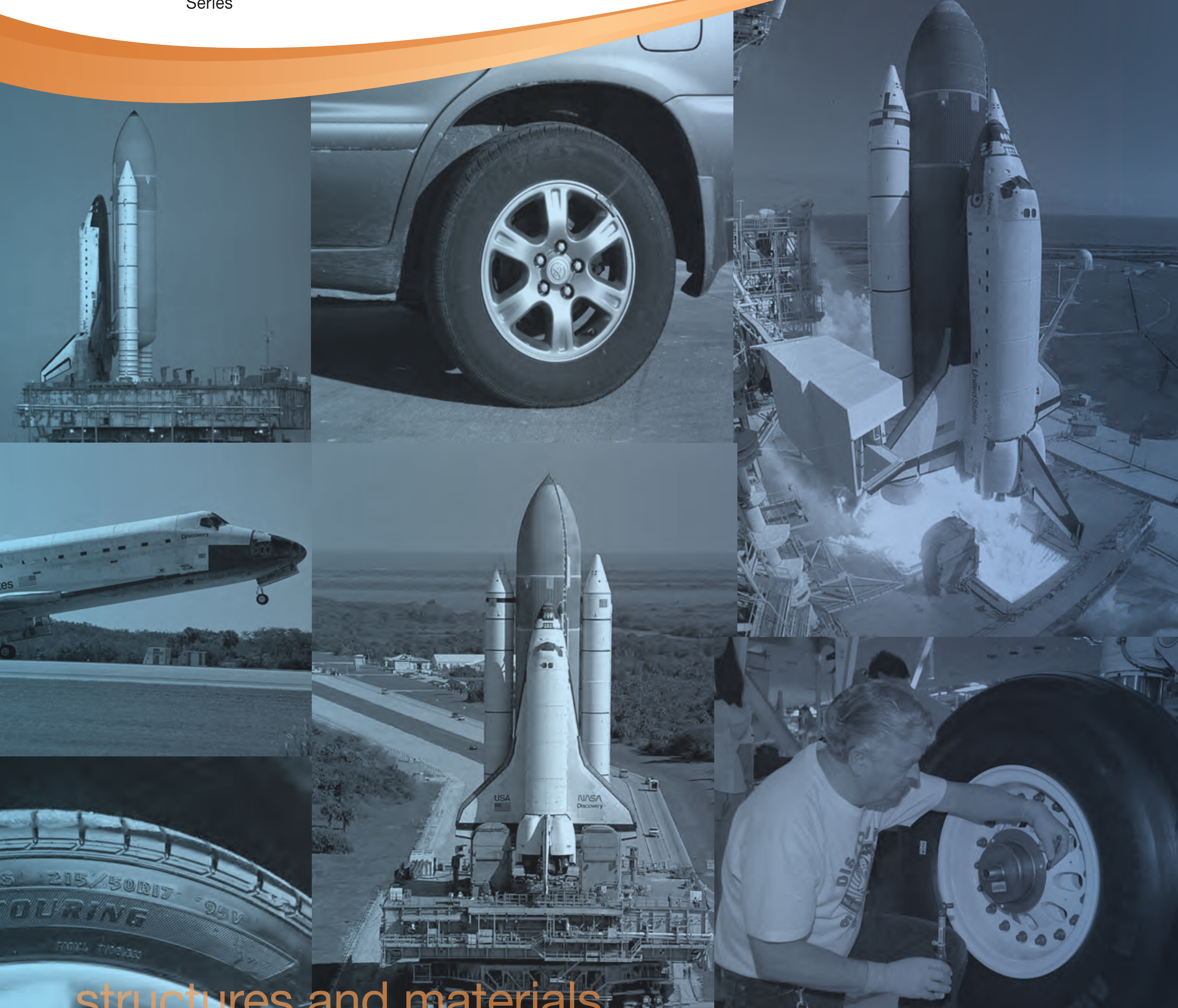
Museum in a BOX Series



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