the Henry Ford®

grades 3-8

Science, Life Skills and Innovations in

American Automobile Racing

Racing in America

Educator DigiKit

Transportation in America

mission statement

The Henry Ford provides unique educational experiences based on authentic objects, stories and lives from America's traditions of ingenuity, resourcefulness and innovation. Our purpose is to inspire people to learn from these traditions to help shape a better future.

overview

Scientific concepts such as Newton's laws, inertia, momentum, forces, Bernoulli's principle, centripetal force, kinetic and potential energy, heat energy, electrical energy and changes of energy are much easier to understand when illustrated with exciting, real-world examples. The Science, Life Skills and Innovations in American Automobile Racing Educator DigiKit does just that. Using **The Henry Ford's** collections, including digitized artifacts and oral history interviews with famous race car drivers, engineers and innovators, you and your students will explore the questions ***"How are science concepts demonstrated by auto racing? How do innovations in auto racing make use of science concepts?"***

This Educator DigiKit is divided into two sections:
a **Teacher Guide** and a **Unit Plan**.

The Teacher Guide section includes resources to complement the Unit Plan. You will find a glossary, a timelines, context-setting activities, a bibliography, curriculum links and curriculum-supporting field trip suggestions.

The Unit Plan section follows the Teacher Guide and includes lesson plans, student handouts, answer keys, culminating project ideas, extension activities, and review and assessment questions. Many of the lessons include use of digitized artifacts from the collections of **The Henry Ford** that can be accessed through the hyperlinks in the Unit Plan or at our website, TheHenryFord.org/education. If you cannot incorporate the whole unit into your schedule, use the lessons or activities most relevant to your needs.

This Educator DigiKit promotes educational use of **The Henry Ford's** extensive Transportation in American Life collections. We hope you and your students will find these resources engaging and relevant.

These resources are made possible, in part, by the generous funding of the Ford Foundation.

contents

These lesson plans have been created for a wide range of ages, abilities and background levels. Teachers are encouraged to use them as appropriate by scaling activities up or down to best meet students' needs.

Please refer to the online version of the Educator DigiKits for the most updated links and content.

teacher guide | for grades 3-8

Glossary

Acceleration
The rate at which an object's velocity changes; $a = \Delta v / \Delta t$.

Acceleration due to gravity
The downward acceleration of an object due to the gravitational attraction between the object and the Earth or other large body.

Aerodynamics
The way the shape of an object affects the flow of air over, around or under it.

Airfoil
A wing-like device on a race car that creates downforce as the air flows over it.

Air resistance
The force created by air when it pushes back against an object's motion; air resistance on a car is also called drag.

Artifact
A man-made object representing a specific time or culture.

Bernoulli's principle
Air moving faster over the longer path on a wing causes a decrease in pressure, resulting in a force in the direction of the decrease in pressure.

Centripetal force
A force toward the center that makes an object move in a circle rather than in a straight line.

Conversion
Changing from one set of units to another, such as from miles per hour to meters per second.

Displacement
The distance and the direction that an object moves from the origin.

Distance
The change of position from one point to another.

Downforce
An aerodynamic force on a car that pushes it downward, resulting in better traction.

Electrical energy
Energy derived from electricity.

Force
Any push or pull.

Frame of reference
The coordinate system for specifying the precise location of the point or frame to which motion is compared.

Friction
The opposing force between two objects that are in contact with and moving against each other.

Gravity
The natural pull of the Earth on an object.

Ground effects
The effects from aerodynamic designs on the underside of a race car, which create a vacuum.

Inertia
An object's tendency to resist any changes in motion.

Joule
The unit of measurement for energy; 1 joule = 1 kilogram-meter^2/second^2.

Kinetic energy
Energy of motion. Kinetic energy = ½ mass * velocity^2, or $KE = ½ m v^2$.

Mass
The amount of matter in an object.

Momentum
The combined mass and velocity of an object. Momentum = mass * velocity, or $p = m * v$.

Continued…

Glossary Continued

Potential energy
Energy due to position; stored energy, or the ability to do work.

Power
Rate of doing work, or work divided by time.

Pressure
Force divided by area.

Relative motion
The comparison of the movement of one object with the movement of another object.

Roll bar
A heavy metal tube or bar wrapped over the driver in race cars; the roll bar prevents the roof from crushing the driver during a rollover.

Safety features
In an automobile, things that make the car safer or that make racing safer.

Speed
The distance an object travels divided by the time it takes to travel the distance.

Thermal energy
Heat energy.

Trade-off
A term that describes how an improvement made in one area might decrease effectiveness in another area.

Velocity
The speed of an object, including its direction. Velocity = change in distance over time, or $v = \Delta d / \Delta t$.

Venturi effect
The effect produced by narrowing a passage of air as the air travels, causing an increase in the speed of the air, a drop in pressure and a force in the direction of the air passage.

Watt
A measurement of power. One watt is 1 joule of work per 1 second.

Weight
The force of gravity pulling on an object; weight equals mass times the acceleration due to gravity.

Work
The force on an object times the distance through which the object moves as the work is converted to either potential energy or kinetic energy.

Unit Plan Timeline

Race Cars

from the Collections of **The Henry Ford**

1901 Ford "Sweepstakes" – Henry Ford's first race car, which gives him publicity that helps him gain financing for his company.

1902 Ford "999" – Henry Ford's second race car, first driven by Barney Oldfield, which gains more positive publicity for Henry Ford.

1906 Locomobile "Old 16" Vanderbilt Cup race car, typical of pre-WW I race cars.

1907 Ford "666"– the car that Henry Ford intends to set land speed records, but it does not.

1956 Chrysler 300, a real production car, or true "stock car," sponsored by Karl Kiekhaeffer.

1959 Willys "Gasser," one of the most successful drag race cars of all time, converted into dragster and driven by George Montgomery.

1960 Slingshot drag racer, in which the driver actually sits behind the rear wheels, like a rock in a slingshot.

1965 Goldenrod, a streamlined racer that sets a land speed record of 409.277 mph.

1967 Ford Mark IV race car, driven by Dan Gurney and A. J. Foyt, which wins the 24 Hours of Le Mans.

1984 March 84C Cosworth Indianapolis race car, driven by Tom Sneva; a typical Indianapolis race car of the 1980s, it has wings to keep it on the ground

1987 Ford Thunderbird, a typical NASCAR stock car driven by Bill Elliott, has only a passing resemblance to street cars.

Important Events in American Automobile Racing

1895 The Duryea brothers enter the first American auto race as a way of testing and advertising their car.

1902 The first top speed runs are held on the beach at Daytona Beach, Florida.

1910 The first high-banked wooden speedway is built at Playa Del Rey in Southern California.

1911 The first Indianapolis 500 race is held.

1947 Bill France organizes mechanics and drivers into the National Association for Stock Car Auto Racing, called NASCAR.

1955 The National Hot Rod Association begins holding national championships for drag racing.

1959 Daytona International Speedway opens in Florida as one of NASCAR's most popular races.

1960s Paved tracks take over in popularity from dirt racetracks.

1960s Television cameras begin to follow auto racing, covering the Indianapolis 500 as well as NASCAR events.

1970 The Indy 500 begins drawing heavy sponsorship from auto-related products, such as spark plugs and oil, as well as non-auto-related firms like Proctor & Gamble (the makers of Tide) and Dean Van Lines.

1977 Janet Guthrie is the first woman to qualify at the Indianapolis 500.

1992 Lyn St. James becomes the first woman to win Indianapolis 500 Rookie of the Year honors.

2001 Dale Earnhardt's death at the 2001 Daytona 500 shocks NASCAR and leads to its adoption of numerous safety devices.

Unit Plan Timeline Continued

National Events

1903 The Wright brothers make their first successful flight.

1906 San Francisco experiences the great earthquake.

1917 The United States enters World War I.

1919 The 19th Amendment gives women the right to vote.

1929 The U.S. stock market crashes; the Great Depression begins.

1959 - 1975 The Vietnam War.

1967 Detroit experiences civil unrest.

1982 Honda begins car production in the United States.

2001 Terrorists hijack passenger planes, crashing them in New York City, Washington, D.C., and Pennsylvania.

World Events

1899 The Boer War begins in South Africa.

1909 Robert Peary and Matthew Henson reach the North Pole.

1914 World War I begins in Europe.

1917 Lenin leads the Bolshevik revolution in Russia, laying the groundwork for the Soviet Union.

1939 World War II begins.

1948 An assassin kills India's Mahatma Gandhi.

1969 Neil Armstrong sets foot on the moon.

1994 Nelson Mandela is elected as the first black South African president; apartheid ends.

2002 The euro becomes the cash currency for 12 European nations.

Context-Setting Activities

These activities are excellent ways to prepare and excite your students for the *Science, Life Skills and Innovations in American Automobile Racing* unit or for a visit to **The Henry Ford.**

Safety in Automobiles

Ask the students to list at least 5 items in their family car that ensure a safe ride. Give a prize or extra credit to the student who comes up with the least-obvious feature. Have the students write their lists on the board. Discuss when each particular safety feature was first added to a passenger car. Ask the students if they know of any safety features that are no longer used because they have been replaced by something newer or perhaps less expensive.

The Future of Automobiles

Ask the students to describe what they think will be the future of the automobile in 5, 10 or 20 years. The students should consider what size cars might be in the future, what safety features might be added, what systems such as GPS systems or guidance systems might be available and what fuel cars might use.

Safety and Car Accidents

Ask the students if they have ever been in an automobile accident. Have them think about and describe how science and technology play a role in protecting them in such accidents. Discuss what physics concepts might be involved in automobile accidents.

Bibliography

Print

Bentley, Ross. *Speed Secrets: Professional Race Driving Techniques*. Minneapolis: Motorbooks, 1998.

Casey, Robert. *The Model T: A Centennial History.* Baltimore: Johns Hopkins Press, 2008.

Dooling, Michael. *The Great Horseless Carriage Race*. New York: Holiday House, 2002.

Earnhardt, Dale and Jade Gurss. *Driver #8*. New York: Warner Books, 2002.

Kulling, Monica. *Eat My Dust! Henry Ford's First Race*. New York: Random House Books for Young Readers, 2002.

Martin, Mark. *NASCAR for Dummies.* Hoboken, NJ: Wiley Publishing, 2009.

Mattern, Joanne. *Behind Every Great Driver: Stock Car Teams*. Danbury, CT: Children's Press, 2007.

Johnstone, Michael. *NASCAR*. New York: Lerner Publishing, 2002.

Otfinoski, Steve. *Around the Track: Race Cars Then and Now*. New York: Benchmark Books, 1997.

Patrick, Danica and Laura Morton. *Danica: Crossing the Line*. New York: Fireside, 2007.

Schaefer, A. R. *The History of NASCAR Racing*. New York: Capstone Press, 2005.

Stewart, Mark. *Auto Racing: A History of Fast Cars and Fearless Drivers*. London: Franklin Watts, 2009.

Online Teacher Resources

thehenryford.org
The official website of **The Henry Ford**.

oninnovation.com
The Henry Ford's project to collect the stories of today's visionaries including auto racing innovators.

racinginamerica.com
The official website of the upcoming Racing in America exhibit in *Henry Ford Museum*.

From the Curators: Racing in America
thehenryford.org/education/erb/RacinginAmerica.pdf
Information on American auto racing from the curators of **The Henry Ford.**

petroleummuseum.org
The website of the Chaparral Gallery at the Permian Basin Petroleum Museum in Midland, Texas. Many innovations in automobile racing throughout history are on display at this museum and its website, which includes web pages for Jim Hall's Chaparral Racing Cars.

nascar.com
The official website of NASCAR racing. This site gives the history of stock-car racing and of drivers of the past and present, and it updates all the current NASCAR races and standings.

daytonainternationalspeedway.com
The official website for the Daytona 500 NASCAR racetrack.

indianapolismotorspeedway.com
The official website of the Indianapolis 500 Motor Speedway in Indianapolis, Indiana.

mispeedway.com
The official website of the Michigan International Speedway in Brooklyn, Michigan.

americanhistory.si.edu/onthemove/themes/story_66_1.html
Website on American Racing: A Diversity of Innovation, a theme within the Smithsonian's America on the Move exhibition.

nhra.com
The official website of the National Hot Rod Association.

indycar.com
The official website of the Indy Racing League.

Connections to National and Michigan Standards and Expectations

Michigan Grade Level Content Expectations

The Science, Life Skills and Innovations in American Automobile Racing unit plans meet Michigan Grade Level Content Expectations for grades 3-8. However, grade 3 teachers should consider introducing the lessons' concepts rather than assigning activity sheets, depending on students' background knowledge.

Science

S.RS.03.11
Demonstrate scientific concepts through various illustrations, performances, models, exhibits and activities.

S.RS.03.16
Identify technology used in everyday life.

S.RS.03.17
Identify current problems that may be solved through the use of technology.

P.FM.3.35
Describe how a push or a pull is a force.

P.FM.3.36
Relate a change in motion of an object to the force that caused the change of motion.

P.FM.03.37
Demonstrate how the change in motion of an object is related to the strength of the force acting upon the object and to the mass of the object.

P.FM.03.38
Demonstrate when an object does not move in response to a force, it is because another force is acting on it.

P.FM.03.41
Compare and contrast the motion of objects in terms of direction.

P.FM.03.42
Identify changes in motion.

P.FM.03.43
Calculate the speed of an object based on the distance it travels divided by the amount of time it took to travel that distance.

S.RS.04.11
Demonstrate scientific concepts through various illustrations, performances, models, exhibits and activities.

S.RS.04.16
Identify technology used in everyday life.

S.RS.04.17
Identify current problems that may be solved through the use of technology.

S.RS.05.15
Demonstrate scientific concepts through various illustrations, performances, models, exhibits and activities.

S.RS.05.16
Design solutions to problems using technology.

P.FM.05.31
Describe what happens when two forces act on an object in the same or opposing directions.

P.FM.05.32
Describe how constant motion is the result of balanced (zero net) forces.

P.FM.05.33
Describe how changes in the motion of objects are caused by a nonzero net (unbalanced) force.

P.FM.05.34

Relate the size of change in motion to the strength of unbalanced forces and the mass of the object.

P.FM.05.41

Explain the motion of an object relative to its point of reference.

P.FM.05.42

Describe the motion of an object in terms of distance, time and direction, as the object moves and in relationship to other objects.

P.FM.05.43

Illustrate how motion can be represented on a graph.

S.RS.06.15

Describe what happens when two forces act on an object in the same or opposing directions.

S.RS.06.16

Design solutions to problems using technology.

S.RS.06.19

Describe how science and technology have advanced because of the contributions of many people throughout history and across cultures.

P.EN.06.11

Identify kinetic energy and potential energy in everyday situations.

S.RS.07.16

Design solutions to problems using technology.

S.RS.07.19

Describe how science and technology have been advanced because of the contributions of many people throughout history and across cultures.

National Science Education Standards

Standard 1: Science as Inquiry

All students should develop:

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

Standard 2: Physical Science

All students should develop an understanding of:

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Standard 5: Science and Technology

All students should develop:

- Abilities of technological design
- Understandings about science and technology

Standard 7: History and Nature of Science

All students should develop understanding of:

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Lesson 1
Life Skills and Automobile Racing

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P.FM.03.42
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S.RS.06.15
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S.RS.07.19
Describe how science and technology have been advanced because of the contributions of many people throughout history and across cultures.

Lesson 2 Newton's Three Laws and Racing

Michigan Grade Level Content Expectations

Science

S.RS.03.17
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P.FM.3.35
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S.RS.06.19
Describe how science and technology have advanced because of the contributions of many people throughout history and across cultures.

S.RS.07.19
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Lesson 3 Forces Involved in Automobile Racing

Michigan Grade Level Content Expectations

Science

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S.RS.03.17
Identify current problems that may be solved through the use of technology.

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P.FM.03.42
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Describe what happens when two forces act on an object in the same or opposing directions.

S.RS.06.19
Describe how science and technology have advanced because of the contributions of many people throughout history and across cultures.

S.RS.07.19
Describe how science and technology have advanced because of the contributions of many people throughout history and across cultures.

Lesson 4 Motion and Energy in Automobile Racing

Michigan Grade Level Content Expectations

Science

S.RS.03.17
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P.FM.05.42
Describe the motion of an object in terms of distance, time and direction, as the object moves and in relationship to other objects.

P.FM.05.43
Illustrate how motion can be represented on a graph.

S.RS.06.15
Describe what happens when two forces act on an object in the same or opposing directions.

P.EN.06.11
Identify kinetic energy and potential energy in everyday situations.

Lesson 5 Ground Effects, Innovations and Safety in Automobile Racing

Michigan Grade Level Content Expectations

Science

S.RS.03.11
Demonstrate scientific concepts through various illustrations, performances, models, exhibits and activities.

S.RS.03.16
Identify technology used in everyday life.

S.RS.03.17
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S.RS.05.15
Demonstrate scientific concepts through various illustrations, performances, models, exhibits and activities.

S.RS.05.16
Design solutions to problems using technology.

P.FM.05.41
Explain the motion of an object relative to its point of reference.

S.RS.06.16
Design solutions to problems using technology.

S.RS.06.19
Describe how science and technology have advanced because of the contributions of many people throughout history and across cultures.

S.RS.07.16
Design solutions to problems using technology.

S.RS.07.19
Describe how science and technology have been advanced because of the contributions of many people throughout history and across cultures.

Field Trip Learning Enhancements

Classes are encouraged to take field trips suggested by the websites that follow, in order to learn about physics, engineering and technology:

The Henry Ford
20900 Oakwood Blvd
Dearborn, MI 48124-4088
thehenryford.org

Detroit Science Center
5020 John R St.
Detroit, MI 48202-4045
detroitsciencecenter.org

Roush Fenway Racing Museum
4600 Roush Place NW
Concord, NC 28027
roushfenwaycorporate.com/Museum

Chaparral Gallery of the Permian Basin Petroleum Museum
1500 Interstate 20 West
Midland, TX 79701
petroleummuseum.org

NASCAR Hall of Fame
400 E. Martin Luther King Blvd.
Charlotte, NC 28202
nascarhall.com

Daytona International Speedway
1801 W. International Speedway Blvd.
Daytona Beach, FL 32114
daytonainternationalspeedway.com

Michigan International Speedway
12626 U.S. Highway 12
Brooklyn, MI 49230
mispeedway.com

unit plan | for grades 3-8

Science, Life Skills and Innovations in American Automobile Racing
Unit Plan Overview

Overarching Questions

How are science concepts demonstrated by auto racing? How do innovations in auto racing make use of science concepts?

Key Concepts

- Passion
- Finding your fit
- Self-confidence
- Learning from mistakes
- Teamwork
- Organization
- Education
- Learn by doing
- Artifact
- Acceleration
- Air resistance
- Force
- Friction
- Inertia
- Mass
- Momentum
- Relative motion
- Speed
- Aerodynamics
- Air resistance
- Velocity
- Centripetal force

Key Concepts Continued

- Downforce
- Gravity
- Trade-offs
- Bernoulli's principle
- Kinetic energy
- Potential energy
- Power
- Thermal energy
- Venturi effect
- Watt
- Weight
- Work
- Airfoil
- Ground effects
- Pressure
- Roll bar
- Safety features

Lessons and Main Ideas

Lesson 1
Life Skills and Automobile Racing

- The skills required to succeed in automobile racing are also helpful general life skills.

Lesson 2
Newton's Three Laws and Racing

- Newton's three laws of motion – the law of inertia, F=ma and action and reaction – can be illustrated with examples from automobile racing.

Lesson 3
Forces Involved in Automobile Racing

- Forces can be illustrated with examples from automobile racing.

Lesson 4
Motion and Energy in Automobile Racing

- Velocity, acceleration, forces, work and energy can be illustrated with examples from automobile racing.

Lesson 5
Ground Effects, Innovations and Safety in Automobile Racing

- Science, physics and engineering principles help explain ground effects and safety innovations in automobile racing.

Continued...

Unit Plan Overview Continued

Duration 5-10 class periods (45 minutes each)

- Lesson Plans: 5 class periods
- Culminating Project: 1-5 class periods, depending on the project chosen

Digitized Artifacts
from the Collections of **The Henry Ford**

Lesson 2
Newton's Three Laws and Racing

- Willys Gasser, 1958 (side view ID# THF69391)
- Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671
- Start of the Indianapolis 500 Race, 1937 ID# THF68313
- Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472
- March 84C Race Car, 1984 (cockpit view ID# THF69363)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 ID# THF69258
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Race Car "999" Built by Henry Ford, 1902 ID# THF70568
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446

Lesson 3
Forces Involved in Automobile Racing

- Soap Box Derby Car, 1939 ID# THF69252
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472
- Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328
- Composite Image Depicting Henry Ford and Spider Huff Driving the Sweepstakes Racer at Grosse Pointe Racetrack, 1901 ID# THF24696
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446
- March 84C Race Car, 1984 (cockpit view ID# 69363)
- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)
- Start of the Indianapolis 500 Race, 1937 ID# THF68313
- Barber-Warnock Special Race Car in Pit at Indianapolis Motor Speedway, 1924 ID# THF68329
- Henry Ford Driving the 999 Race Car Against Harkness Race Car at Grosse Pointe Racetrack, 1903 ID# THF23024

Lesson 4
Motion and Energy in Automobile Racing

- Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)
- March 84C Race Car, 1984 (aerial view ID# THF69371)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (side view ID# THF69258) (aerial view ID# THF69260)

Unit Plan Overview Continued

- Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472

Lesson 5
Ground Effects, Innovations and Safety in Automobile Racing

- March 84C Race Car, 1984 (aerial view ID# THF69371) (side view ID# THF69368)
- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024
- Start of the Indianapolis 500 Race, 1937 ID# THF68313
- Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671

Racing Oral History Interviews

- Carroll Shelby: Passion
- Jim Dilamarter: Finding Your Fit
- Jim Hall: Self-Confidence
- Lyn St. James: Learning from Mistakes
- Al Unser, Sr.: Teamwork
- Lyn St. James: Organization
- Jim Dilamarter: Education
- Jim Hall: Learn by Doing
- Jim Hall: Safety Rules
- Jim Hall: Engineer to Go Faster
- Dan Gurney: Innovations to Get More Force
- Bobby Unser: Getting More Force from Better Tire Traction
- Carroll Shelby: Kinetic Energy and Brakes
- Jim Dilamarter: Getting Downforce and Pushing Air

Materials

- Computer with access to the Internet; digital projector and screen (preferred) OR printed handouts of the digitized artifacts and descriptions
- Bulletin board
- Construction paper and materials for decorating the bulletin board
- Calculators
- Background Information Sheet for Students 2A: Newton's Three Laws and Racing
- Student Activity Sheet 2B: Newton's Three Laws
- Answer Key 2B: Newton's Three Laws
- Background Information Sheet for Students 3A: Forces Involved in Auto Racing
- Student Activity Sheet 3B: Forces
- Answer Key 3B: Forces
- Background Information Sheet for Students 4A: Motion and Energy in Automobile Racing
- Student Activity Sheet 4B: Distance, Velocity and Acceleration (Grades 4–5)
- Student Activity Sheet 4C: Distance, Velocity and Acceleration (Grades 6–8)
- Answer Key 4B and C: Distance, Velocity and Acceleration (Grades 4–5 and 6–8)
- Background Information Sheet for Students 5A: Ground Effects, Innovations and Safety in Automobile Racing
- Student Activity Sheet 5B: Ground Effects and Safety Innovations in Automobile Racing
- Answer Key 5B: Ground Effects and Safety Innovations in Automobile Racing
- Culminating Projects
- Extension Activities
- Student Activity Sheet 6: Review/Assessment Questions
- Answer Key 6: Review/Assessment Questions

Lesson 1
Life Skills and Automobile Racing

Main Idea

The skills required for success in automobile racing are also helpful general life skills.

Key Concepts

- Passion
- Finding your fit
- Self-confidence
- Learning from mistakes
- Teamwork
- Organization
- Education
- Learn by doing
- Artifact

Racing Oral History Interviews

- Carroll Shelby: Passion
- Jim Dilamarter: Finding Your Fit
- Jim Hall: Self-Confidence
- Lyn St. James: Learning from Mistakes
- Al Unser, Sr.: Teamwork
- Lyn St. James: Organization
- Jim Dilamarter: Education
- Jim Hall: Learn by Doing

Materials

- Computer with access to the Internet; digital projector and screen (preferred) OR printed handouts of the digitized artifacts and descriptions
- Bulletin board
- Construction paper and other materials for decorating the bulletin board

Duration 1 class period (45 minutes)

Instructional Sequence

1 Introduction

To introduce the idea that we can learn life skills from people involved in auto racing, ask students the following questions:

- Have you seen an automobile race in person or on television?
- Would you like to be a race car driver, engineer or mechanic? Why or why not?

2 Using the Racing Oral History Interviews

Discuss with your class that being a successful race car driver, engineer or mechanic requires many of the same skills that other jobs do. Show the Racing Oral History Interviews to find out what skills and qualities contributed to the success of these racers, engineers and mechanics. Ask students individually to choose an interview, explain how the quality inspiring the title relates to automobile racing and give an example of how they or others can demonstrate the quality.

Continued…

Lesson 1 Life Skills and Automobile Racing Continued

- Carroll Shelby: Passion
- Jim Dilamarter: Finding Your Fit
- Jim Hall: Self-Confidence
- Lyn St. James: Learning from Mistakes
- Al Unser, Sr.: Teamwork
- Lyn St. James: Organization
- Jim Dilamarter: Education
- Jim Hall: Learn by Doing

Tell students that in the upcoming lessons they will be following in the footsteps of Jim Hall: They will be learning science concepts and applying those concepts to real-life situations in automobile racing.

3 Encouraging Life Skills

To encourage students to develop the life skills discussed in the interviews, create a bulletin board in your room with a headline for each skill. Define the word "artifact" with students (see the Glossary in the Teacher Guide). Ask students to each bring in an artifact that demonstrates one of these life skills. For example, a student might bring in a basketball if basketball is her passion, or a student who has gotten poor grades in the past might bring an assignment that earned a good grade as an example of learning from mistakes. Have students share their artifacts with the class. Then display the artifacts (take a picture of the student with the artifact or, if possible, post the artifact itself) on the bulletin board under the headline of the appropriate life skill.

This activity will also familiarize the students with the idea of artifacts, which will be helpful as they work with digitized artifacts from the collections of **The Henry Ford** during this unit.

Lesson 2
Newton's Three Laws and Racing

Main Idea

Newton's three laws of motion – the law of inertia, F=ma and action and reaction – can be illustrated with examples from automobile racing.

Key Concepts

- Acceleration
- Air resistance
- Force
- Friction
- Inertia
- Mass
- Momentum
- Relative motion
- Speed
- Velocity

Digitized Artifacts
from the Collections of **The Henry Ford**

Lesson 2 Newton's Three Laws and Racing

- Willys Gasser, 1958 (side view ID# THF69391)
- Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671
- Start of the Indianapolis 500 Race, 1937 ID# THF68313
- Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472
- March 84C Race Car, 1984 (cockpit view ID# THF69363)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 ID# THF69258
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Race Car "999" Built by Henry Ford, 1902 ID# THF70568
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446

Racing Oral History Interviews

- Jim Hall: Safety Rules
- Jim Hall: Engineer to Go Faster

Materials

- Computers with access to the Internet; digital projector and screen (preferred) OR printed handouts of Background Information Sheet, Student Activity Sheet and digitized artifacts' images and descriptions
- Background Information Sheet for Students 2A: Newton's Three Laws and Racing
- Student Activity Sheet 2B: Newton's Three Laws
- Answer Key 2B: Newton's Three Laws

Duration 1-2 class periods (45 minutes each)

Continued…

Lesson 2 Newton's Three Laws and Racing Continued

Instructional Sequence

1 Looking for Laws of Motion in Automobile Racing

Distribute Background Information Sheet for Students 2A: Newton's Three Laws and Racing. If possible, access this sheet online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet. Instruct students to listen to the racing oral history interviews and examine the digitized artifacts. (See the Background Information for Teachers section below for additional information on the digitized artifacts.)

Use the Background Information Sheet to review, read and discuss with students the questions for analysis, concepts, and information about Isaac Newton and his laws of motion as they apply to automobile racing.

Encourage students to make their own observations, ask questions and offer other examples from life that illustrate Newton's laws of motion.

2 Background Information for Teachers

Additional information on the digitized artifacts is provided below to supplement what is offered on the website and to assist your students in the completion of the Background Information Sheet and Student Activity Worksheet.

– March 84C Race Car, 1984
(cockpit view ID# THF69363)

Notice the wide tires, designed for better grip in the turning. The front and rear wings generate downforce to help the car hold the road. The bodywork under the car, called the side pods, is carefully shaped to create lower pressure under the car than above, which pulls the car down tighter to the road.

– Buck & Thompson Class D Slingshot Dragster, 1960
ID# THF36041

Dragsters are designed to do one thing – cover a quarter-mile from a standing start as quickly as possible. This car contains no extra weight – nothing that does not contribute to that goal. This chassis was actually built from a kit, and the entire car was built and raced by two young men from Rockford, Illinois – Bob Thompson and Sam Buck.

– Willys Gasser, 1958 (side view ID# THF69391)

Cars like this were enormously popular for drag racing in the 1950s and 1960s. In the 1930s, Willys were small, lightweight economy cars with excellent acceleration and were a favorite of drag racers.

– Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446

Automobile racing has always been a dangerous sport for both drivers and fans. Sometimes things go terribly wrong. Here, the car has crashed through the fence when it continued in a somewhat straight line instead of making the left-hand turn. Look back behind the fence to see that the car did not make the curve. This is an example of Newton's first law. It could also represent Newton's second law, as there was not enough force between the tires and the track to cause the car to accelerate around the curve.

Assessment

Assign students Student Activity Worksheet 2B: Newton's Three Laws to assess learning and understanding.

Newton's three laws and Racing

Questions for Analysis

- What are Newton's laws of motion?
- How do Newton's laws of motion apply to automobile racing today?

Key Concepts

Acceleration

The rate at which an object's velocity changes;
$a = \Delta v / \Delta t$.

Air resistance

The force created by the air when it pushes back against an object's motion.

Force

Any push or pull.

Friction

The opposing force between two objects that are in contact with and moving against each other.

Inertia

An object's tendency to resist any changes in motion.

Mass

The amount of matter in an object.

Momentum

The combined mass and velocity of an object, or mass times velocity.

Safety features

In an automobile, things that make the car safer or that make racing safer.

Speed

The distance an object travels divided by the time it takes to travel the distance.

Velocity

The speed of an object, including its direction.

Weight

The force of gravity pulling on an object. Weight equals mass times the acceleration due to gravity.

Background

Isaac Newton was an English physicist and mathematician who lived from 1642 to 1727. He worked in many areas of physics, but he is primarily known for his three laws of motion. These laws of motion can help us describe the speed, acceleration, thrills and dangers of automobile racing.

Continued...

Racing Oral History Interviews

Listen to Jim Hall talk about changing force and changing how fast cars will go. He also discusses how he works within the rules and yet still tries to find ways to make his car go faster.

– Jim Hall: Safety Rules

– Jim Hall: Engineer to Go Faster

Newton's First Law – The Law of Inertia

Newton's first law is called the law of inertia. Inertia is the resistance to change in motion. Newton's first law states that a body at rest remains at rest and that a body in motion remains in motion unless acted upon by an outside force. This law means that once we start moving, we continue moving.

In everyday life, we exhibit inertia because we tend to keep doing what we are already doing. When we are up, we like to stay up. If we are sitting or sleeping, we like to stay sitting or sleeping.

If a car is standing still without the motor running, the car will remain there. Look at the picture of the drag race car sitting in front of *Henry Ford Museum*. [Willys Gasser, 1958 (side view ID# THF69391)] As long as the engine is not started and no one pushes this car, it will remain where it is.

If a driver starts the engine and pushes the accelerator, the motor produces a force that moves the car forward. The driver and passengers feel as though they are thrown or pushed backwards, but actually the car goes forward and the driver and passengers remain where they are. When the car accelerates forward and the car seats hit them in their backs, they feel as though they are being thrown backwards.

Newton's first law can also be seen in a car that is stationary and gets hit in the rear end. The driver feels as if he or she flies backwards, but actually the car is pushed forward, leaving the driver behind.

There are many safety features designed to protect race car drivers. Race cars have high-backed seats so that when the drivers accelerate forward, their entire body goes forward with the car. Look at the picture of the inside of Lyn St. James's race car with its tall car seats. [Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671] Racecar drivers' heads do not snap back because they are up against a tall seat. In your family car, your car's head rests and seats keep you from feeling as though you are thrown backwards.

Once race cars reach a high rate of speed, they continue at the high rate of speed, according to Newton's first law. [Start of the Indianapolis 500 Race, 1937 ID# THF68313] If there is a crash and the car is stopped by an outside force (for example, another car or a wall), the driver keeps on going. Safety belts help slow the driver to prevent him or her from flying out of the car or from hitting the front windshield. In a passenger car, air bags slow the driver and passenger.

In a modern race car, the race car safety belts are called 5-point belts. They go around both shoulders as well as around the waist and down to the center of the front of the seat, and they attach at 5 points. Modern race drivers also use a HANS Device, which wraps around the driver's neck to help protect his or her neck from flying side to side. Five-point belts and HANS Devices help protect race car drivers from the effects of Newton's first law.

Continued…

Look at the picture of an Indy race car. [March 84C Race Car, 1984 (cockpit view ID# THF69363)] In serious auto racing accidents, especially those that involve Indy-style cars (called open wheel race cars), many pieces of the car fly off. Why is it actually good that parts fly off the race car? Rather than the energy going into the driver, the kinetic energy can be dissipated in the flying parts. Roll bars are also used to prevent the car from crushing around the driver.

Newton's Second Law – F = ma

Newton's second law can be stated mathematically as force equals mass times velocity, written as F = ma. An unbalanced force will create acceleration. The greater is the force, the greater will be the acceleration. The greater the mass, the less the acceleration. Thus a car with larger mass will accelerate more slowly.

What do car builders and engineers do to increase acceleration and speed? Race car designers and innovators aim for the most powerful engine possible, for more force and acceleration. The designers also want to make the car lighter so that the car has better acceleration and speed. Most races regulate engine size, so designers or car builders cannot put too large an engine in their race car. Therefore, race car builders try to make cars lighter where possible, by using aluminum or plastic rather than steel, which is heavier. Many wheel rims are made from lightweight magnesium to decrease mass in the car.

Look how light the 1960 Slingshot dragster looks. [Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041] The Slingshot car is very light. It is designed and built for drag racing, where the track is straight and only a quarter-mile long.

Notice the 1902 Ford 999 race car built by Henry Ford. [Race Car "999" Built by Henry Ford, 1902 ID# THF70568] The 999 car had a large, 1,150-cubic-inch engine to provide a large force to make it accelerate and go fast. Notice how heavy the 999 car is; its weight slows it down.

Newton's Third Law – Action and Reaction

Newton's third law states that for every action in one direction, there is an equal and opposite reaction. Another way to state the third law is for every force in one direction, there is an equal and opposite force in the other direction.

When a race car accelerates, the motor and engine transfer force to the tires, which push backwards against the pavement. The pavement or track pushes back on the race car. Because forces cause objects to accelerate, the car moves forward. When two forces push against each other, the lighter object moves farther and faster.

Thus the car moves rather than the track. If there is gravel or dirt on the track, then the track does move, in a way: You see the gravel or dirt fly back as the car goes forward.

There are numerous examples of action and reaction in everyday situations. When a jet is flying, the engine forces hot gas out in one direction and the jet flies in the opposite direction. A swimmer pulls water backward to propel forward. A bullet is shot out of a gun in one direction and the gun recoils in the opposite direction.

Sometimes motion is expressed by the term momentum. The momentum of an object, such as a race car, is the combination of its mass and its velocity. When two objects push against each other, they go in opposite directions, and the momentum in one direction equals the momentum in the other direction.

Newton's three laws

Name

1. In the space below, state Newton's first law in your own words. List three examples of Newton's first law:

2. In the space below, state Newton's second law in your own words. List three examples of Newton's second law.

3. In the space below, state Newton's third law in your own words. List three examples of Newton's third law.

4. For each statement below, write 1st, 2nd or 3rd, according to which law of motion the statement best represents:

A ______ You place a can of cola on the dashboard in front of you. When the car accelerates forward, the cola dumps on your lap.

B ______ You are standing on a skateboard. You jump off the skateboard in one direction, and the skateboard goes flying in the opposite direction.

C ______ A car is stuck in snow. One person can't get the car moving, but with the help of three friends, the car can be pushed out of the snow.

D ______ When you are swimming, you pull your hand back through the water and then you go forward.

E ______ Once a space shuttle reaches orbit, it just continues in orbit without any more propulsion.

Newton's three laws

1. In the space below, state Newton's first law in your own words. List three examples of Newton's first law:

Newton's first law is called the law of inertia. The law states that a body at rest remains at rest and a body in motion remains in motion unless acted upon by an outside force.

Examples can include any example of an object remaining in motion or remaining at rest, such as:

- A *A race car waiting to start a race will remain still.*
- B *Once a race car is moving, it keeps on moving.*
- C *When a person is in a car and the car suddenly brakes or stops, the passenger keeps on going unless a seat belt or air bag restrains him or her.*

2. In the space below, state Newton's second law in your own words. List three examples of Newton's second law.

Newton's second law is F = ma or Force = mass times acceleration. An unbalanced force produces acceleration. The acceleration is proportional to the force and inverse to the mass.

Examples include any statement about larger forces producing more acceleration or less massive objects accelerating faster, such as:

- A *A large engine will accelerate a car faster than a small engine.*
- B *The more massive a car, the slower it will accelerate.*
- C *Several people can push a car more easily than one person can.*

3. In the space below, state Newton's third law in your own words. List three examples of Newton's third law.

Newton's third law concerns action and reaction. It states that for every action in one direction, there is an equal and opposite reaction. The third law can be stated that for every force in one direction, there is an equal force in the opposite direction.

Examples include any in which one object propels in one direction and another object propels in the opposite direction, such as:

A When a cannon ball is shot forward, the cannon recoils.

B When you push against a wall, the wall pushes back against you.

C In order to throw a baseball or softball forward, your feet must push back against the ground. If you are wearing flat shoes on wet grass, your feet will slip when you try to throw any object.

.

4. For each statement below, write 1st, 2nd or 3rd, according to which law of motion the statement best represents:

A *1st* You place a can of cola on the dashboard in front of you. When the car accelerates forward, the cola dumps on your lap.

B *3rd* You are standing on a skateboard. You jump off the skateboard in one direction, and the skateboard goes flying in the opposite direction.

C *2nd* A car is stuck in snow. One person can't get the car moving, but with the help of three friends, the car can be pushed out of the snow.

D *3rd* When you are swimming, you pull your hand back through the water and then you go forward.

E *1st* Once a space shuttle reaches orbit, it just continues in orbit without any more propulsion.

Lesson 3
Forces Involved in Automobile Racing

Main Idea

Forces can be illustrated with examples from automobile racing.

Duration 1 class period (45 minutes)

Key Concepts

- Acceleration
- Aerodynamics
- Air resistance
- Centripetal force
- Downforce
- Force
- Friction
- Gravity
- Inertia
- Trade-offs

Racing Oral History Interviews:

- Dan Gurney: Innovations to Get More Force
- Bobby Unser: Getting More Force from Better Tire Traction

Digitized Artifacts

from the Collections of **The Henry Ford**

Lesson 3 Forces Involved in Automobile Racing

- Soap Box Derby Car, 1939 ID# THF69252
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472
- Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328
- Composite Image Depicting Henry Ford and Spider Huff Driving the Sweepstakes Racer at Grosse Pointe Racetrack, 1901 ID# THF24696
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446
- March 84C Race Car, 1984 (cockpit view ID# 69363)
- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)
- Start of the Indianapolis 500 Race, 1937 ID# THF68313
- Barber-Warnock Special Race Car in Pit at Indianapolis Motor Speedway, 1924 ID# THF68329
- Henry Ford Driving the 999 Race Car Against Harkness Race Car at Grosse Pointe Racetrack, 1903 ID# THF23024

Continued...

Lesson 3 Forces Involved in Automobile Racing Continued

Materials

– Computers with access to the Internet; digital projector and screen (preferred) OR printed handouts of Background Information Sheet, Student Activity Sheet and digitized artifacts' images and descriptions
– Background Information Sheet for Students 3A: Forces Involved in Automobile Racing
– Student Activity Sheet 3B: Forces
– Answer Key 3B: Forces

Instructional Sequence

1 Introduction

Ask students to describe some of the physical forces involved in their everyday life. Explain that a force is simply a push or pull and that there are many types of forces.

2 Using the Racing Oral History Interviews

Discuss with your class how they might find a way to increase force for a race car. Use the Racing Oral History Interviews to show how engineers and race drivers use innovative tactics to get more force for their cars. Dan Gurney talks about innovative ways to get more force from the engine, and Bobby Unser discusses using crushed batteries and walnuts in tires to get better traction.

– Dan Gurney: Innovations to Get More Force
– Bobby Unser: Getting More Force from Better Tire Traction

3 Finding Forces in Automobile Racing

Distribute Background Information Sheet for Students 3A: Forces Involved in Automobile Racing. If possible, also access this sheet online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.

Have the students closely examine the digitized images, and ask them to explain the forces illustrated in the images. (See the Background Information for Teachers section below for additional information on digitized artifacts.)

Use the Background Information Sheet and the digitized artifacts to review, read and discuss with students the key forces involved in automobiles:

A Force from the engine
B Force of gravity
C Centripetal force
D Air resistance force
E Downforce to keep the car on the road
F Friction forces, including the tire on the road, internal engine friction, wind friction and friction in the gears.

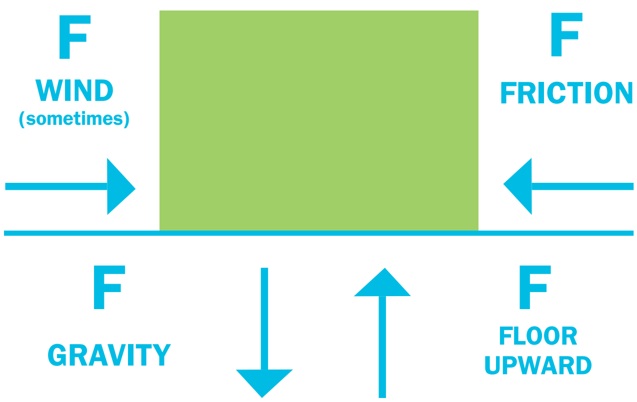
Encourage students to make their own observations, ask questions and offer other examples of forces.

Discuss the concept of net forces. A net force is an unbalanced force. Forces that are balanced do not cause accelerations or changes of speeds. A car sitting on the road experiences the downward force of gravity. The car does not move, because the track or ground provides an upward force equal to the downward force of gravity, resulting in a net force of zero. A car does not start moving until the engine force is greater than the friction and counter forces.

Continued…

4 Representing Forces

Discuss with your class how to represent forces with free body diagrams. A free body diagram is a simple sketch in which all the forces are represented with arrows and labeled. Longer arrows represent more force. The diagram should be very simple. For example, below is a diagram of a box sitting on the floor. In this example, all arrows should be equal and opposite to show that the box will not move.



5 Background Information for Teachers

Formulas Involving Force:

- F = m * a (In the metric system, force is measured in Newtons (N), mass in kilograms (kg) and acceleration in m / s^2.)
- a = F / m
- Momentum during a reaction: m * v = m * v (momentum before = momentum after).
- v = Δ d / Δ t (measured in m/sec)
- a = Δ v / Δ t

The additional information below on the digitized artifacts supplements the information at the website and will help your students complete the Student Activity Worksheet.

Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472 shows that a car starting at rest will remain at rest. The car is not moving because it is a stationary object with forces balanced.

Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328 illustrates that four people produce more force, and therefore more acceleration, than one person alone could produce. Even today cars are usually pushed to the starting line at every racetrack in order not to waste any fuel by driving them before the race begins.

Composite Image Depicting Henry Ford and Spider Huff Driving the Sweepstakes Racer at Grosse Pointe Racetrack, 1901 ID# THF24696 shows a heavier, or more massive, earlier car. This car was Henry Ford's first race car. He was seeking to rebuild his reputation as an automobile engineer after the failure of his first automobile company, so he built this car with the help of his friends Ed "Spider" Huff and Oliver Bartel. In this race, Henry Ford defeated a much better-known car manufacturer and driver, Alexander Winton. Winton's car was faster, but it developed engine problems during the 10-mile race. Ford's victory helped him get financing for his second automobile company. Henry Ford later left that company and formed his third company, which became a success.

Continued…

Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041 shows a lightweight car that accelerated easily. This car was built to go strictly in a straight line and had no "extras," in order to keep it very light.

Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446 shows an early car crash at a race. The race car has crashed through the wall and has come to a stop, which illustrates several concepts. If you look at the upper left, you can see that the car was attempting to traverse a left-hand curve. The car must have continued in a straight line (according to Newton's first law of motion) instead of making the curve. There was obviously not enough centripetal force to keep the car turning to the left. The tires may not have allowed enough friction, the car might have been bumped by another car or perhaps the steering system malfunctioned. You can see that this race car was not going as fast as the cars of today, whose high speeds will cause them to break apart if they hit a wall as this car did.

March 84C Race Car, 1984 (cockpit view ID# 69363) shows wide racing tires. In general, according to theories of physics, surface area does not affect the amount of friction; friction instead depends only on moisture and surface materials. However, the slick wide tires of modern NASCAR and Indianapolis race cars enable them to hold the road best both in curves and during accelerations. The grooves of modern passenger car tires allow rain and moisture to escape from under the tires to prevent skidding and sliding.

Willys Gasser, 1958 (front view ID# THF69394) shows the flat front of the Gasser. The shape of this car would certainly cause a great amount of air resistance, requiring the car to push the air. The force of the air against the car would slow the Gasser's acceleration and speed. To decrease the air resistance from its large, flat front, the top of the Gasser was chopped off and lowered.

Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260) has a front designed to allow air to travel smoothly up and over the car with low resistance. The shape of the car also allows the air to provide downforce on the car and help it stick to the track during cornering.

Henry Ford Driving the 999 Race Car Against Harkness Race Car at Grosse Pointe Racetrack, 1903 ID# THF23024 shows a rider sitting on the running board on the left-hand side of the car. The rider creates downforce on the left side of the car to keep it from tipping over while going around left-hand curves. Early race cars had a high center of gravity, or center of mass, and could easily roll over in cornering. Compare the car in this photo to modern race cars that are built with a very low center of gravity to prevent rollovers in fast cornering. Notice the similarity to modern sailboat racing, where sailors lean over the side to keep from tipping over while cornering in the wind. The running-board rider was also able to warn the driver of engine problems if he was driving too fast. In modern race cars, onboard computers monitor every system, and the crew chief communicates with the driver.

Assessment

Assign students Student Activity Sheet 3B: Forces to assess their learning and understanding.

forces involved in Automobile Racing

Key Concepts

- Acceleration
- Centripetal force
- Friction
- Inertia
- Trade-off
- Air resistance
- Downforce
- Force
- Gravity

More about Force

In simple terms, a force is any push or pull. There are numerous types of forces that we encounter every day. We can analyze many of these forces through examples taken from automobile racing.

An unbalanced force will cause acceleration and make an object increase or decrease its speed. When two forces equally oppose each other, we say they are balanced. A balanced force does not cause acceleration. Think of a tug of war: If the forces from opposite teams are equal or balanced, neither team moves.

A car sitting on the racetrack has forces on it, but they are balanced. Look at the picture of the soapbox derby car [Soap Box Derby Car, 1939 ID# THF69252]. The force of gravity pulls down on the car while an equal force from the track pushes up. The forces are balanced, and the car remains stationary. If the soapbox derby car were on a hill, the downward force would be greater than the upward force and the car would accelerate down the hill. Before a race begins, a race car's engine has not yet started to provide a forward force, and the car remains at rest, like these drag racing cars [Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472].

In order to get a car to move, there must be an unbalanced force. Look at this race car which has gone off the track. [Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328] Notice that it takes several people to accelerate the car by pushing it. A large force is needed to overcome friction, a backwards force opposing motion, and a simple method of getting the car to the starting line is simply to push it, overcoming the friction between the tires and the track.

Forces on Larger Cars

It takes a lot of force to accelerate a large car. In one of the earliest race cars – the Sweepstakes built by Henry Ford – the motor was extremely large to provide a lot of force. The motor and the rest of the car were massive. This early car raced at only about 60 miles per hour. [Composite Image Depicting Henry Ford and Spider Huff Driving the Sweepstakes Racer at Grosse Pointe Racetrack, 1901 ID# THF24696] The Sweepstakes was effective in its day because other cars were also very heavy. Note the difference between the Sweepstakes and the 1960 Slingshot Dragster drag race car [Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041]. The Slingshot Dragster has a smaller engine than the Sweepstakes but is much lighter, so it can go faster. In most races today, all the race cars are required to have the same mass in order to keep the races competitive.

Continued…

Centripetal Force

Another force involved in racing is centripetal force. When a car is traveling in a circle or on a curve, centripetal force pulls the car back toward the center of the circle or curve. Some racetracks are banked to push the car back toward the center. The banked turn helps provide centripetal force.

Most people think that when a car is traveling around a curve, the car is being forced out of the circle. Actually, the car naturally moves straight. Newton's first law states that a body in motion remains in motion unless acted upon by an outside force. To keep a car on a curved track, an inward force, toward the center, must be applied to the car to keep it on the track. Try to analyze the unusual accident in this photo [Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446].

Note that the car has crashed through the fence. Look back at the track in the upper left. You can see that the car should have gone around a left-hand curve, but it obviously didn't make the curve. For a race car to stay on the track around a curve, there must be an inward force. The tires pushing against the road or pavement should provide the inward force to keep the car in a circle; they did not provide enough force this time.

Tire Forces

Tires are very important in racing and have evolved over the years. Look at the tires on the Ford Thunderbird NASCAR-style car. [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)] Note the large tires, designed to grip the road. Race cars can go through several tires during a long race because friction between the tires and the pavement wears tires out rapidly.

Other Problems

Look at the picture of Henry Ford and his friend Spider Huff, with Ford in the driver's seat [Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024]. Note the man sitting on the running board on the left side of the car. Imagine sitting on the small running board, racing and bouncing down the road at 60 miles per hour. What do you think the man on the running board is doing?

Newton's first law says that an object in motion (in this case, the car) will continue in motion unless acted upon by a force. When the driver makes a left-hand turn, the race car actually tends to go straight. The grip of the tires on the track provides force to turn the car. But early cars were not stable. The bottom of the car, where the tires are located, turned, while the heavy top of the car tried to keep going straight. These cars tended to roll over while turning.

So why did the rider ride on the left side? Most races are on oval tracks and run counterclockwise, so the drivers are constantly turning left around curves. Since the early race cars on these tracks could not corner very fast without rolling over to the right, the rider provided extra weight, or a downforce, on the left side of the car to balance the car and keep it from rolling over.

The running-board rider on these early race cars also served another purpose. Can you guess what it is? The rider watched the engine to make certain that it was running properly. He could warn the driver to slow down if there was an engine or gear problem, and if needed, he could actually oil the motor while racing.

Continued…

In modern race cars, on-board computers monitor the entire system; the computers send information back to the engineers in the pits so that necessary adjustments can be made to the race cars during pit stops. Compare what you may have seen happening in a modern pit stop with this picture of an older pit stop during a car race [Barber-Warnock Special Race Car in Pit at Indianapolis Motor Speedway, 1924 ID# THF68329].

Center of Gravity

The weight of modern race cars is very low to the ground; they have what is called a low center of gravity. The center of gravity is the average center of all the weight. If their center of gravity is too high, cars can tip over while going around sharp turns. Lowering the center of gravity or weight helps keep cars from rolling over.

Drag Force, or Wind Resistance Force

A large force in racing is wind resistance, or drag. At high rates of speed, the air pushing against the front of the car produces great force opposing the race car's forward speed.

Innovators are constantly redesigning cars to cut down on wind resistance by shaping the front of the car. Look at Willys Gasser, 1958 (front view ID# THF69394) and (side view ID# THF69391). The shape of this car would certainly cause a great amount of air resistance, requiring the car to push the air. The force of the air against the car would slow the Gasser's acceleration and speed. To decrease the air resistance from its large, flat front, the top of the Gasser was chopped off and lowered.

Notice the difference between the shape of the Gasser and the Ford Thunderbird [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view) ID# THF69260]. The front of the Gasser pushed a lot of air, but the Thunderbird has a sloped front that allows air to pass over the top of the car with less resisting force.

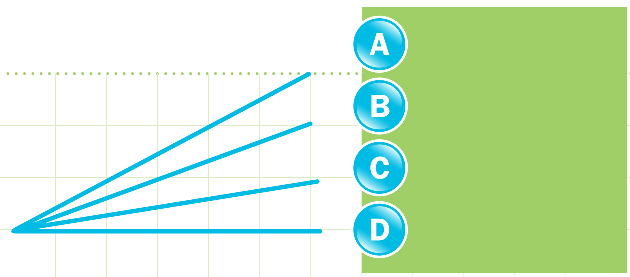
When the Gasser's owner, George Montgomery, finally retired the Willys, he replaced it with a modified Mustang that was much lower and had better aerodynamics.

forces

Name ______________________________

1. One of the ways to analyze forces is to make a sketch called a free body diagram. A free body diagram, a very simple sketch, includes arrows that represent all the forces. Make a sketch of a book sitting on a table and draw arrows to represent the forces involved.

2. The drawing below shows 4 different possible roadbed angles during a left-hand curve. Explain which banking angle would allow the greatest racing speed, which would allow the least racing speed and why.

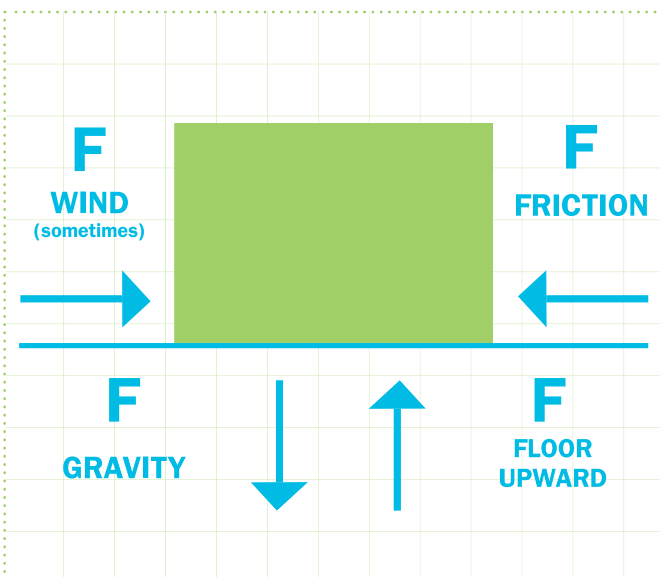


3. Sketch a car that would have the best aerodynamics (ability to move through the wind with the least resistance).

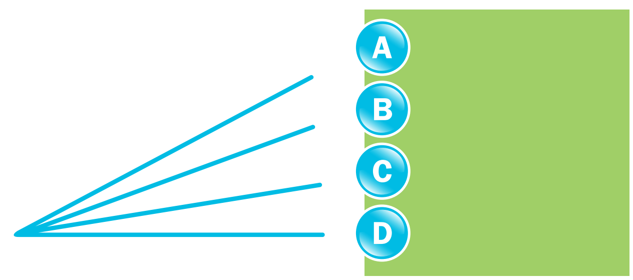
forces

1. One of the ways to analyze forces is to make a sketch called a free body diagram. A free body diagram, a very simple sketch, includes arrows that represent all the forces. Make a sketch of a book sitting on a table and draw arrows to represent the forces involved.

   In this example, all arrows should be equal and opposite to show that the box will not move.



2. The drawing below shows 4 different possible roadbed angles during a left-hand curve. Explain which banking angle would allow the greatest racing speed, which would allow the least racing speed and why.



   Angle A allows the greatest racing speed, and Angle D allows the least racing speed.

   A banked turn provides an added inward force that keeps the tires from sliding, thus allowing greater speeds. The more the turn is banked, the faster the cars can race around the turns. The level track does not assist the grip of the tires at all in a turn.

3. Sketch a car that would have the best aerodynamics (ability to move through the wind with the least resistance).

   Students will have a variety of sketches with the front end of the car slanted. Students should show some of the curves they have seen on cars.

Lesson 4
Motion and Energy in Automobile Racing

Main Idea

Velocity, acceleration, forces, work and energy can be illustrated with examples from automobile racing.

Key Concepts

- Acceleration
- Bernoulli's principle
- Force
- Mass
- Power
- Velocity
- Watt
- Work
- Aerodynamics
- Downforce
- Kinetic energy
- Potential energy
- Thermal energy
- Venturi effect
- Weight

Racing Oral History Interview

- Carroll Shelby: Kinetic Energy and Brakes

Digitized Artifacts
from the Collections of **The Henry Ford**

Lesson 4 Motion and Energy in Automobile Racing

- Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)
- March 84C Race Car, 1984 (aerial view ID# THF69371)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (side view ID# THF69258) (aerial view ID# THF69260)
- Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472

Materials

- Computers with access to the Internet; digital projector and screen (preferred) OR printed handouts of Background Information Sheet, Student Activity Sheets and digitized artifacts' images and descriptions
- Calculators
- Background Information Sheet for Students 4A: Motion and Energy in Automobile Racing
- Student Activity Sheet 4B: Distance, Velocity and Acceleration (Grades 4-5)
- Student Activity Sheet 4C: Distance, Velocity and Acceleration (Grades 6-8)
- Answer Key 4B/C: Distance, Velocity and Acceleration (Grades 4-5)/(Grades 6-8)

Duration 1 class period (45 minutes)

Instructional Sequence

1 Engagement

Discuss with students the concepts of distance, speed, velocity force and energy. Ask them to discuss the various speeds that they have experienced. Typical speeds are: 3-4 mph for walking, 10-20 mph for riding a bike, 25-40 mph in a car traveling locally and 70 mph for a car on the freeway. A cross-country train might travel at 100 mph, and a commercial airliner typically travels at 400 to 500 mph.

Continued...

2 Discovering Types of Motion and Energy in Automobile Racing

Distribute Background Information Sheet for Students 3A: Motion and Energy in Automobile Racing. If possible, access this sheet online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet. (See the Background Information for Teachers section below for additional information on formulas, speed and energy.)

Use the Background Information Sheet to review, read and discuss with students the question for analysis, concepts and information about motion and energy in automobile racing.

Encourage students to make their own observations, ask questions and offer other examples from life that illustrate motion and energy.

3 Background Information for Teachers

Formulas involving motion and energy:

Distance = velocity * time $d = v * t$

Velocity = change in distance / change in time

$v = \Delta d / \Delta t$

Time = distance / velocity $t = d / v$

Acceleration = change in velocity / time

$a = \Delta v / \Delta t$

Velocity = acceleration * time $v = a * t$

Work = Force * distance $W = F * d$

Power = Work / time $P = W / t$

One horsepower = 746 watts 1 hp = 746 watts

One watt = 1/746 hp = .00134 hp

Kinetic energy (KE) = $\frac{1}{2} m * v^2$

Note

Speed is a measure of distance traveled per time. Velocity is technically displacement per time, where displacement is distance and direction from the origin; velocity is speed and direction. For the purpose of this lesson, and for work with most students who are younger, speed and velocity can be used interchangeably.

In an automobile, chemical energy in gasoline or fuel is converted to thermal energy or heat energy. Thermal energy is then converted to mechanical energy. Mechanical energy is then converted to kinetic energy of motion.

Starting at a light, a car will be motionless because the engine force is balanced by the braking force, and the car remains at rest. The car will accelerate as long as the engine force is greater than all the friction forces (wind, tires on the road, moving parts in the engine, gears, etc.). If a car is accelerated to a cruising speed of 40 mph, then to continue at a constant 40 mph, friction forces will need to be balanced by the engine force. If on an expressway the driver presses harder on the accelerator, making the engine force greater than the friction forces, then when the car reaches and maintains a cruising speed of 70 mph, the engine force will again need to equal all the friction forces. When the engine force is reduced, the car will decelerate as the friction forces, including braking, become greater than engine force. If the driver presses firmly on the brake, friction forces will become greater than the engine force, and the car will decelerate to a stop.

Assessment

Assign students Student Activity Worksheet 4B/C: Distance, Velocity and Acceleration to assess their learning and understanding.

motion and energy in Automobile Racing

Motion and Energy

Automobile racing involves various forms of energy and various types of motion. Race car engineers and designers are constantly coming up with new innovations to make their cars travel faster and more safely.

Question for Analysis

How do we use the concepts of kinetic energy, work and power to evaluate automobile racing?

Concepts

Acceleration

The rate at which an object's velocity changes; $a = \Delta v / \Delta t$

Aerodynamics

The way the shape of an object affects the flow of air over, around or under it.

Bernoulli's principle

Air moving faster over the longer path on a wing causes a decrease in pressure, resulting in a force in the direction of the decrease in pressure.

Downforce

The aerodynamic force on a car that pushes it downward, resulting in better traction.

Force

Any push or pull.

Kinetic energy

Energy of motion. The formula for kinetic energy is $KE = \frac{1}{2} m v^2$, or ½ the mass times the velocity squared.

Mass

The amount of matter or substance in an object.

Potential energy

Energy due to position, or stored energy.

Power

Rate of doing work, or work divided by time; $P = W / t$

Speed

The distance an object travels divided by the time it takes to travel that distance.

Thermal energy

Heat energy.

Velocity

The speed of an object, including its direction. Velocity = change in distance over time, or $v = \Delta d / \Delta t$

Venturi effect

The effect produced by narrowing a passage of air as the air travels, causing an increase in the speed of the air, a drop in pressure and a force in the direction of the air passage.

Watt

A measurement of power. One watt is 1 joule of work per 1 second. A joule of work is 1 Newton of force acting through 1 meter.

Weight

The force of gravity pulling on an object, or the mass of the object times its acceleration due to gravity.

Work

The force on an object times the distance through which the force moves the object as the work is converted to energy of motion.

Continued...

Using the Racing Oral History Interview

View the oral history of Carroll Shelby as he talks about kinetic energy and brakes. Notice that he explains that the car's brakes can turn its kinetic energy of motion into heat energy.

Carroll Shelby: Kinetic Energy and Brakes

Speed, or Velocity, and Acceleration in Auto Racing

The speed of a car is measured by the distance the car covers in a certain amount of time. The formula for speed is s = d / t, or speed equals distance divided by time. A car that travels 100 miles in 2 hours would be traveling 50 miles per hour, since its speed = 100 miles / 2 hours = 50 miles / hour. Or, distance can be calculated by multiplying speed or velocity times time. So if a car is traveling 120 miles / hour, it will travel 360 miles in 3 hours. d=v * t, distance = 120 miles/hour * 3 hours = 360 miles.

Often, speed, or velocity, is measured in meters per second. A car that travels 200 meters in 8 seconds would be traveling 25 meters/second, since speed = 200 meters/8 second = 25 meters/second. If we work in meters per second, we can calculate the distance in meters. A car traveling at 40 meters/second for 10 seconds will travel 400 meters, since distance = 40 meters/second * 10 seconds = 400 meters.

Velocity is technically called displacement/time. Displacement is both distance and direction, while velocity is speed in a particular direction. Often, as in this Background Information Sheet, speed and velocity are used interchangeably.

Kinetic and Potential Energy

Kinetic energy is energy of motion. Kinetic energy is usually measured using meters and seconds. Kinetic energy equals one-half the mass of an object times its velocity squared ($KE = ½ m * v^2$). A toy car with a mass of 2 kilograms traveling at 10 meters/second will have 100 kilogram-meters^2/second^2, or what we call 100 joules; the unit of energy when measured in kilogram-meters^2/second^2 is the joule. So $KE = ½ * 2$ kilograms * (10 meters/second)^2 , or ½ * 2 * 10 * 10 = 100 kilogram-meters^2/second^2, or 100 joules.

A race car has a lot of kinetic energy. Look at the picture of the red #9 NASCAR race car [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 ID# THF69258]. The mass of this car is about 1,588 kilograms (3,500 pounds). If it travels at 180 miles/hour, or about 80 meters/second, its kinetic energy will be:

$KE = ½ m * v^2 = ½ * 1{,}588 * 80 * 80 = 5{,}081{,}600$ joules.

Potential energy is the energy due to the position of the object. A rock on the edge of a building's roof has the potential to fall and turn into kinetic energy. Potential energy can also be energy stored chemically, like the energy stored in gasoline.

Thermal energy is energy due to heat, or heat energy. When an automobile engine burns fuel, the potential energy in the fuel is turned into thermal energy – heat – that operates the pistons to change the thermal energy into kinetic energy, or energy of motion. The pistons then move a crankshaft that is attached to the wheels and makes them move.

Continued…

Work and Horsepower

The work done by the engine to create kinetic energy to move the car is measured differently than the way we normally think of work. The amount of work that a car engine can produce is measured in horsepower. The concept of horsepower was created by James Watt, who lived from 1736 to 1819. He measured the amount of weight a horse could move a certain distance in a given time and came up with 33,000 foot-pounds/minute, which he called 1 horsepower (1 hp). Thus an engine with 350 horsepower could do the work of 350 horses.

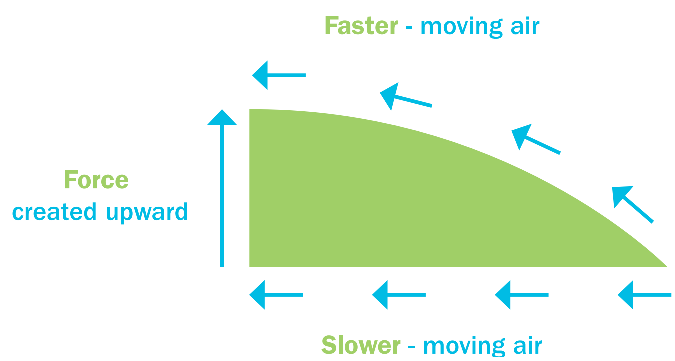
Work is measured by multiplying the amount of force on an object by the distance an object is moved by the force. Work equals force times distance ($W = F * d$). Work is measured in a unit called joules.

Power is a measure of how fast work can be completed. Power is work divided by time ($P = W / t$). Power is measured in watts, and 1 watt is 1 joule per second. One horsepower is equivalent to 746 watts.

Bernoulli's Principle and Energy

One of the most interesting aspects of automobile racing involves Bernoulli's principle. Fast-moving air produces a drop in air pressure and a force in the direction of the drop in pressure. If you look at a wing of an airplane, you will see that the top of the wing has a longer surface than the bottom of the wing (see Fig.1). The air has to travel faster over the longer upper surface. The faster-moving air produces a drop in pressure above the wing, giving the bottom of the wing comparatively higher pressure. There will be a force created from the pressure difference, and that force will push, or lift, the wing upward.

Fig. 1



Airfoils

Race car engineers use Bernoulli's principle to make winglike objects called airfoils. The "wing" of the airfoil is turned upside down so that the longer surface is on the bottom. The airfoil is attached to either the front or the back of the car to push down on it and gain better traction. Look at the airfoil on the Texaco Star race car [March 84C Race Car, 1984 (aerial view ID# THF69371)].

Air resistance can also be used to force a car down. Air hits the front of a race car that has a low front and continues over the top, actually pushing down on the front of the car and giving better traction. Look at the front of the red #9Ford Thunderbird [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)]. Notice that its low front causes the oncoming air to push down on the front of the car.

Designs of race cars are always being improved to allow the cars to travel faster.

Name

distance, velocity and acceleration
(Grades 4-5)

Formulas

Distance = velocity * time $d = v * t$

Velocity = distance / time $v = \Delta d / \Delta t$

Time = distance / velocity $t = d / v$

Acceleration = change in velocity / time $a = \Delta v / \Delta t$

Velocity = acceleration * time $v = a * t$

Work = force * distance $W = F * d$

1. During the Indianapolis 500, a winning driver can often cover the 500 miles in 3 hours. What would be his average velocity?

2. The land speed record set by the Goldenrod Racer [Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676] was 409 miles per hour (mph). A NASCAR racer can travel 180 mph. A bicycle racer can travel 30 mph. How long would it take each of the three to travel 500 miles?

3. During time trials, a NASCAR racer might reach 210 mph. How far could a NASCAR racer travel in 8 hours if he could continue at that speed?

4. The Willys "Gasser" drag-race car [Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)] could accelerate from 0 to 140 mph (about 63 meters/second) in 12 seconds. What would be its acceleration (measured in meters/second^2)?

5. How much work is done by the pit crew pushing a car with a force of 2,000 Newtons through a distance of 30 meters? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

Name

distance, velocity and acceleration
(Grades 6-8)

Formulas

Distance = velocity * time	d = v * t
Velocity = distance / time	v = Δ d / Δ t
Time = distance / velocity	t = d / v
Acceleration = change in velocity / time	a = Δ v / Δ t
Velocity = acceleration * time	v = a * t
Work = force * distance	W = F * d
Power = work / time	P = W / t
1 horsepower = 746 watts	1 hp = 746 watts

1. A race car makes 34 laps around the Daytona Speedway (1 lap is 2.5 miles). What would be the race car's average velocity if it makes the 34 laps in half an hour?

2. What would be the acceleration of a 1950s drag racer if the car accelerates from 0 to 130 mph (use 58 meters/second) in 12.8 seconds? See digitized artifact Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472.

3. How much work would be done by the engine in a NASCAR stock car that exerts a force of 1,600 Newtons for a 2.0-mile (3,200-meter) lap? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

4. A. What would be the power (in watts) of the car in Problem 3 if it takes 40 seconds to complete the lap?

B. How many horsepower would be used?

5. If the Daytona 500 was won in a time of 2 hours and 40 minutes, what would be the winner's average speed? (Remember, there are 60 minutes in an hour.)

distance, velocity and acceleration
(Grades 4-5)

1. During the Indianapolis 500, a winning driver can often cover the 500 miles in 3 hours. What would be his average velocity?

   v = d / t = 500 miles/ 3 hours = 166.7 miles/hour

2. The land speed record set by the Goldenrod Racer [Summers Brothers "Goldenrod" Land Speed Record Car, 1965 ID# THF37676] was 409 miles per hour (mph). A NASCAR racer can travel 180 mph. A bicycle racer can travel 30 mph. How long would it take each of the three to travel 500 miles?

   Goldenrod land speed racer:
   t = d / v = 500 miles/ 409 miles/hour = 1.22 hours or 1 hour 13 minutes

   NASCAR racer:
   t = d / v = 500 miles/ 180 miles/hour = 2.78 hours or 2 hours 47 minutes

   Bicycle racer:
   t = d / v = 500 miles/ 30 miles/hour = 16.67 hours or 16 hours 40 minutes

3. During time trials, a NASCAR racer might reach 210 mph. How far could a NASCAR racer travel in 8 hours if he could continue at that speed?

   *d=v * t = 210 miles/hour * 8 hr = 1,680 miles*

4. The Willys "Gasser" drag race car [Willys Gasser, 1958 (engine view ID# THF69399) (side view ID# THF69391)] could accelerate from 0 to 140 mph (about 63 meters/second) in 12 seconds. What would be its acceleration (measured in meters/second^2)?

   a = Δ v / Δt = 63 meters/second / 12 seconds = 5.25 meters/second^2

5. How much work is done by the pit crew pushing a car with a force of 2,000 Newtons through a distance of 30 meters? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

   *Work = F * d = 2,000 Newtons * 30 meters = 60,000 joules*

distance, velocity and acceleration

(Grades 6-8)

1. A race car makes 34 laps around the Daytona Speedway (1 lap is 2.5 miles). What would be the race car's average velocity if it makes the 34 laps in half an hour?

   Distance =

   *# laps * 2.5 miles = 34 laps * 2.5 miles/lap = 85 miles*

   Velocity = d / t = 85 miles/ 0.5 hour = 170 miles/hour

2. What would be the acceleration of a 1950s drag racer if the car accelerates from 0 to 130 mph (use 58 meters/second) in 12.8 seconds? See digitized artifact Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472.

   Acceleration = Δ v / Δ t = 58 meters/second/ 12.8 seconds = 4.53 meters/second^2

3. How much work would be done by the engine in a NASCAR stock car that exerts a force of 1,600 Newtons for a 2.0-mile (3,200-meter) lap? (One Newton is the force that accelerates 1 kg at a rate of 1 meter per second each second.)

   *W = F * d = 1,600 Newtons * 3,200 meters = 5,120,000 joules*

4. A. What would be the power (in watts) of the car in Problem 3 if it takes 40 seconds to complete the lap?

   Acceleration = Δ v / Δ t = 58 meters/second/ 12.8 seconds = 4.53 meters/second^2

   B. How many horsepower would be used?

   *128,000 watts * 1 hp/ 746 watts = 172 hp*

5. If the Daytona 500 was won in a time of 2 hours and 40 minutes, what would be the winner's average speed? (Remember, there are 60 minutes in an hour.)

   s = d / t = 500 miles/ 2.67 hour = 187.3 miles/hour

Lesson 5
Ground Effects, Innovations and Safety in Automobile Racing

Main Idea

Science, physics and engineering principles help explain ground effects and safety innovations in automobile racing.

Key Concepts

- Aerodynamics
- Airfoil
- Air resistance
- Bernoulli's principle
- Downforce
- Force
- Ground effects
- Pressure
- Relative motion
- Roll bar
- Safety features

Materials

- Computers with access to the Internet; digital projector and screen (preferred) OR printed handouts of Background Information Sheet, Student Activity Sheet and digitized artifacts' images and descriptions
- Background Information Sheet for Students 5A: Ground Effects, Innovations and Safety in Automobile Racing
- Student Activity Sheet 5B: Ground Effects and Safety Innovations in Automobile Racing
- Answer Key 5B: Ground Effects and Safety Innovations in Automobile Racing

Duration 1 class period (45 minutes)

Racing Oral History Interviews

- Jim Dilamarter: Getting Downforce and Pushing Air

Digitized Artifacts

from the Collections of **The Henry Ford**

Lesson 5 Ground Effects, Innovations and Safety in Automobile Racing

- March 84C Race Car, 1984
(aerial view ID# THF69371)
(side view ID# THF69368)
- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987
(aerial view ID# THF69260)
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903
ID# THF23024
- Start of the Indianapolis 500 Race, 1937
ID# THF68313
- Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671

Continued…

Instructional Sequence

1. Engagement

Ask the students what they know about wind resistance in cars. Ask them if they know how air moving over a car can be used to help the car actually go faster.

2. Exploring Ground Effects and Innovations in Automobile Racing

Distribute Background Information Sheet for Students 5A: Ground Effects, Innovations and Safety in Automobile Racing. If possible, access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet. (See the Background Information for Teachers section below for additional information on Bernoulli's principle and the digitized artifact images.)

Use the Background Information Sheet to review, read and discuss with students the question for analysis, concepts and information about Ground Effects, Innovations and Safety in Automobile Racing.

Encourage students to make their own observations, ask questions and offer other examples from life that illustrate these concepts and principles.

3. Background Information for Teachers

Bernoulli's principle is the overriding concept that makes an airplane stay in the air or makes a race car stay on the track. In an airplane wing, the surface on top of the wing is longer than the bottom surface due to differences in their curves. The faster-traveling air over the longer surface causes lower pressure on the top of the wing, while the bottom of the wing is subject to comparatively higher pressure. This creates a force upward that moves from high pressure to low pressure, and it is this force, caused by pressure difference, that keeps the airplane in flight.

Ask your students if they play baseball or softball and know what causes a baseball or softball to curve in its trajectory. Actually, it's the spin that the pitcher puts on the ball that makes it curve. The side of the ball spinning into wind has slower moving air flowing past it. The side of the ball spinning away from the direction of the throw has a faster moving air flowing past it, setting up a drop in pressure from the side of the slower-moving air to the side of the faster-moving air. The drop in pressure causes a force in that direction and the ball curves with the pressure.

Continued…

Lesson 5 Ground Effects, Innovations and Safety in Automobile Racing Continued

- March 84C Race Car, 1984 (aerial view ID# THF69371). This Texaco Star race car illustrates the airfoils that produce downforce for greater traction in the corners. This picture shows a side view of the race car and its airfoil. Notice the shape of the airfoil, which has a longer surface on the bottom of the wing and a shorter surface on the top. The air traveling over both surfaces gets from front to back in the same time; therefore the air that travels over the longer underside must travel faster than the air that travels over the top side. The faster-moving air causes a drop in pressure underneath the airfoil, and since a force is created toward a drop in pressure, a downforce is created. The downforce will cause greater traction on the track and allow the car to go faster around the curves without skidding off the track. In most races, these airfoils are not allowed because they allow race cars to travel at a higher speed than is considered safe on some race-tracks.
- Willys Gasser, 1958 (front view ID# THF69394). The Willys "Gasser" is a drag race car from the 1950s and 1960s that has a flat nose. The flat surface pushes back on the incoming air and decreases the car's ability to accelerate. To minimize this liability, the top of this car was actually chopped off and lowered to decrease the surface of the flat front.
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260). The red #9 Ford Thunderbird NASCAR-style race car illustrates a front end that slopes for better aerodynamics. The air can ride easily over the top of the car, allowing the Thunderbird to cut through the air resistance.
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024. The picture of this early race car shows a rider on the side of the car. Needless to say, these early race cars were not built for safety.
- Start of the Indianapolis 500 Race, 1937 ID# THF68313. This start of the Indianapolis 500 shows many cars with open tops.
- Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671. This illustration shows how the interiors of modern race cars are different those of older race cars. Identify all the safety features shown in the picture.

Assessment

Assign Student Activity Worksheet 5B: Ground Effects and Safety Innovations in Automobile Racing to assess students' learning and understanding.

ground effects, innovations and safety in Automobile Racing

Question for Analysis

What are the technologies and innovations behind ground effects and safety features in automobile racing?

Introduction

Of the many special innovations and concepts developed over automobile-racing history, most involve science and physics principles that have been expanded and further developed in engineering race cars. Many of these innovations and concepts are used today in our passenger cars.

Concepts

Aerodynamics

The way the shape of an object affects the flow of air over, around or under it.

Airfoil

A winglike device on a race car that creates downforce as the air flows over it.

Air resistance

The force created by the air when it pushes back against an object's motion.

Bernoulli's principle

Air moving faster over the longer path on a wing will cause a decrease in pressure, resulting in a force in the direction of the decrease in pressure.

Downforce

The aerodynamic force on a car that pushes it downward, resulting in better traction.

Force

Any push or pull.

Ground effects

The effects from aerodynamic designs on the underside of a race car, which create a vacuum.

Pressure

Force divided by area.

Relative motion

The comparison of the movement of one object with the movement of another object.

Roll bar

A heavy metal tube or bar wrapped over the driver in a race car; the roll bar prevents the roof from crushing the driver during a rollover.

Safety features

In an automobile, things that make the car safer or that make racing safer.

Oral History Interviews

Watch the following oral history interviews to understand how race car builders work toward innovating new ways to go faster. Al Unser, Sr. also talks about the need for teamwork in order to accomplish any goal.

Racing Oral History Interviews

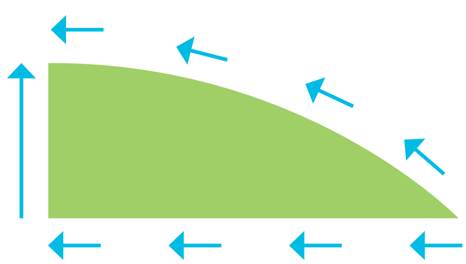
– Jim Dilamarter: Getting Downforce and Pushing Air

Airflow

Race car designs can manipulate the motion of air around the cars through aerodynamics. A ground effect results from an aerodynamic design on the underside of a race car, which creates a vacuum.

One of the most interesting aspects of automobile racing involves Bernoulli's principle. Fast-moving air causes a drop in air pressure and a force in the direction of the pressure drop. If you look at a wing of an airplane, you will see the top of the wing has a longer surface than does the bottom of the wing (see Fig.1). The air has to travel faster over the longer, upper surface. The faster moving air produces a drop in pressure, giving the bottom of the wing comparatively higher pressure, and there will be a force created from the pressure difference. The resulting force will push or lift the wing upward.

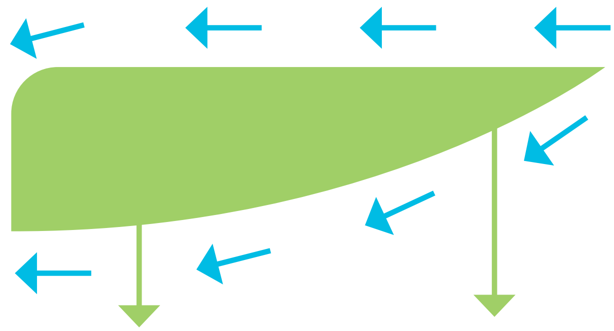
Fig. 1



Airfoils

Race car engineers have used Bernoulli's principle to make winglike objects called airfoils. The "wing" of the airfoil is turned upside down, so that the longer surface is on the bottom. The airfoil is attached to either the front or the back of the car to push down on it and gain better traction. Look at the airfoil on the Texaco Star race car [March 84C Race Car, 1984 (aerial view ID# THF69371)]. The winglike airfoils are attached to the nose of the car and the rear of the car. As the air passes over the airfoil, the pressure difference caused by the air moving faster below the airfoil than above it produces a downforce (see Fig. 2).

Fig. 2



Downforces

The fronts of race cars (and of passenger cars) are slanted downward, not to take advantage of Bernoulli's principle, but simply to allow air to pass over the car without pushing on the front of the car. Notice the front of the red #9 Ford Thunderbird [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (aerial view ID# THF69260)}. The front of the Thunderbird is slanted forward. The forward slant allows two advantages. First, the air rides over the top of the car without pushing straight back against the car so that there is less force opposing the car's motion. Second, there is a downward force on the front of the race car allowing the tires to grip better and the car to corner faster. When the air hits the front of a race car that has a low front and then continues over the top of the car, the air actually pushes down on the front of the car to give better traction (see Fig. 3). Notice the low front on this Thunderbird; it causes the oncoming air to push down on the front of the car.

Fig. 3

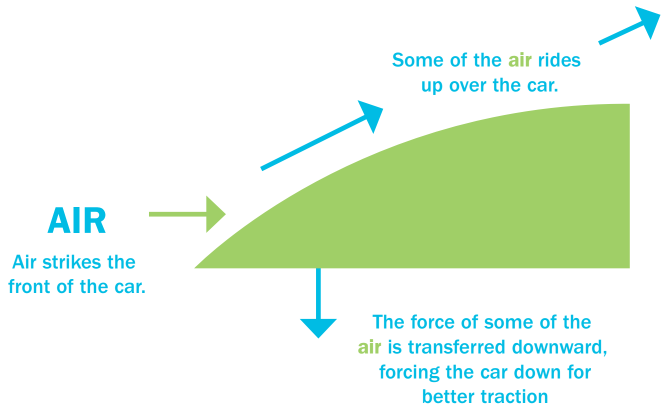
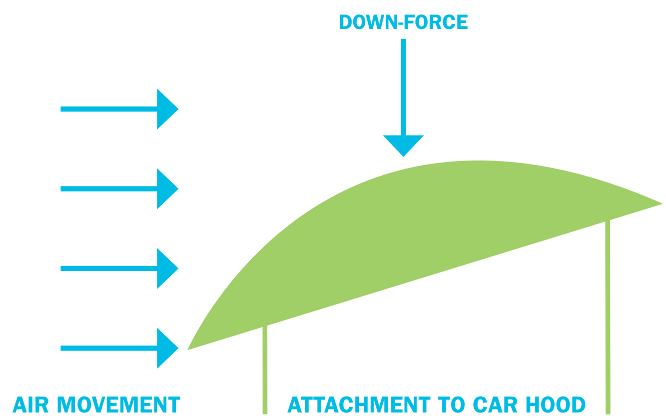


Fig. 4



Sometimes the airfoil itself is tilted so that the airfoil transfers force directly downward to the car. When the air strikes the tilted airfoil, there are two forces produced. Not only is Bernoulli's principle in effect, but the tilt of the airfoil causes a transfer of the force downward. The angle of the airfoil can be adjusted for different racing conditions. If the track has more straight sections, the foil is kept level with the track. If there is a lot of cornering, the foil is tilted to produce more downforce. Notice the airfoils on the 1984 March 84C-Cosworth Indianapolis race car [March 84C Race Car, 1984 (aerial view ID# THF69371)].

Notice how the air moves. The air strikes the front of the airfoil, which is slanted down. The angle of the air against the foil causes a push, or force, downward. The airfoil is attached to the hood and therefore forces the car downward onto the track, allowing greater traction for cornering (see Fig. 4).

There is a drawback to using the airfoil angled downward – it increases the force against the front of the car and slows it down. This presents a trade-off: The car gains cornering ability but loses overall straightaway speed. An airfoil angled downward would only be useful on tracks with short straightaways and a higher percentage of curves.

Safety

Race car designs are always being improved to allow the race cars to travel faster and more safely. The cars have roll bars to strengthen the roof during a rollover. The driver wears a 5-point seat belt that totally and securely straps him or her in. The driver wears fireproof clothing and fireproof gloves. Many safety features that are designed for race cars are later adapted for passenger cars

ground effects, innovations and safety in Automobile Racing

Name ________________________________

1. Draw a sketch that illustrates Bernoulli's principle by drawing an airfoil and then sketching and labeling the air movement and the resulting forces as you imagine them.

2. Look at these pictures of early races: Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024 and Start of the Indianapolis 500 Race, 1937 ID# THF68313. Compare them with these images of more modern race cars: Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671 and March 84C Race Car, 1984 (side view ID# THF69368).

   Use these pictures and your studies to make a list of 10 items below that includes safety issues in the older race cars and safety features of the more modern race cars.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

ground effects, innovations and safety in Automobile Racing

1. Draw a sketch that illustrates Bernoulli's principle by drawing an airfoil and then sketching and labeling the air movement and the resulting forces as you imagine them.

   See the explanation and figure on Background Information Sheet 4A for a sample drawing that illustrates Bernoulli's principle.

2. Look at these pictures of early races: Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024 and Start of the Indianapolis 500 Race, 1937 ID# THF68313. Compare them with these images of more modern race cars: Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671 and March 84C Race Car, 1984 (side view ID# THF69368).

   Use these pictures and your studies to make a list of 10 items below that includes safety issues in the older race cars and safety features of the more modern race cars.

   There are numerous possible answers; here are some of them:

Some safety issues in the older race cars:

1. *Notice the rider on the running board. Notice everything that might happen to him, such as falling off, bumping and getting hit by another car, etc.*
2. *Notice that few of the drivers or riders are wearing a helmet.*
3. *Notice that there are no roll bars.*
4. *There is very little back on the seat to protect the driver's back.*
5. *There are no seat belts in the older cars.*
6. *There is no windshield, so objects can get in drivers' eyes.*

Some safety features of the more modern race cars:

7. *Notice the fire-resistant suit.*
8. *Notice the fire-resistant gloves.*
9. *Notice the high back on the driver's seat to protect the driver's back.*
10. *Notice all the cushioning in the car.*
11. *Notice the 5-point safety belt.*
12. *Notice the strength in all the bars above the driver; these bars hold up the roof during a rollover.*
13. *Notice the driver's helmet.*
14. *Notice the eye shield.*
15. *Notice that the entire seat tends to wrap around the driver.*

supplemental resources | for grades 3-8

Science, Life Skills and Innovations in American Automobile Racing
Culminating Projects

These projects are designed as opportunities for students to demonstrate their learning through this entire unit. Introduce the projects at the outset of the unit Science, Life Skills and Innovations in American Automobile Racing so that students can gather information along the way.

Choose the project option or options that best fit your class's needs:

Individual Project
Designing Paper Airplanes

Design and build a paper airplane. After the airplanes are built, bend one part of the wing so that the airplane will make the following maneuvers when it is thrown:

A Fly straight and far

B Make a nose dive

C Make a rapid turn upward

D Follow a curved path to the left

E Follow a curved path to the right

You and your classmates will vote on the design that performs each of these maneuvers the best.

Online Individual Project
ExhibitBuilder: Curate Your Own Exhibition

Create your own exhibitions through **The Henry Ford** website, using digital artifacts and the ideas and information that you've learned through this unit to design an exhibition to illustrate physics and engineering concepts. Begin with the concept of innovation in auto racing and in automobile design. You might extend the concept to include innovations in other science and technology areas such as flight or electricity. Use **The Henry Ford's** Transportation in American Life website to access ExhibitBuilder – or click here.

Wind Racer Car

Build cars out of any lightweight objects or materials available. Attach some sort of device to each car to act as a sail. The dimensions of the car and attachment should not exceed 10 inches tall, 10 inches wide and 10 inches long. Place a fan in the middle of a hall in your school, aiming it straight down the hall. Mark off a starting line in front of the fan and a finish line 10 feet farther away (or use a longer or shorter distance, according to teacher direction, if desired). Aim your car so that when the fan is turned on, your car will race down the hall for the predetermined distance. Time each car, one car at a time. The winner will be the car that travels the distance from starting line to finish line in the least amount of time.

Biography of a Racer

Write a paper about the life of a current or former race driver. Address some of the following questions in your biography:

A What type of racing has the driver done?

B When did the driver begin racing?

C What influenced his or her decision to become a race car driver?

D What kinds of successes and disappointments has this driver encountered?

E Has the driver been involved in any particular innovative designs for his or her car?

F What does the driver's current car look like?

Science, Life Skills and Innovations in American Automobile Racing
Extension Activities

These extension activities provide additional opportunities for the eager learner curious about topics related to science and auto racing.

Sports and Safety

Begin by asking the students to list the sports equipment they use for an organized sport, such as football or soccer, and for individual sports, such as bicycling, skateboarding or snowboarding. Ask the students to discuss why both athletes and race car driver need safety equipment.

Innovations Paper

Ask the students to write a paper on the innovations in their family car. They should mention as many innovative products as they can that are used both inside and outside the car. Have the students write about or draw new innovations they would design for a future automobile.

Design a Car

Have students design and build cars. The cars should be no longer than 10 inches. They can use old CDs or DVDs as wheels, and the rest of the car may be made of any reasonable material, such as LEGO® bricks, other construction sets or balsa wood. Test each car's speed. Build a racing ramp from a 12-foot length of 10-inch-wide board. Place one end of the board on the floor and the other end of the board on a box or other item that is 12 to 24 inches tall. Use a marker to place a starting line at the top end of the board and a finish line near the end of the board. Time the cars going down the ramp over the set distance. You might also build a second ramp and race the cars side by side in a drag race.

Pit Crew Teamwork Activity

Auto racing pit crew members must learn to work quickly as a team to refuel a race car, put on new tires and make other repairs. Encourage the teamwork skills needed in pit crews by dividing the class into groups or crews of four or five. Give each crew the same number of LEGO bricks or other blocks that are all the same size. The students must work together to build the tallest possible tower out of the blocks in 15, 20 or 30 seconds. Each crew member must take a turn, stacking blocks in exactly the same order each time. No student may stack more than 2 blocks before all other crew members have placed a block. Rotate so that each member gets a turn. Assess which crew cooperates the best, building the highest tower in the least amount of time.

Pit Crew Timing

Auto racing pit crew members must learn to work quickly to refuel a race car, put on new tires and make other repairs. This activity will simulate how fast students can work. The challenge is the same as in the previous activity – to build the tallest possible tower out of the blocks in 15, 20 or 30 seconds – but here each student should be given 10 identical LEGO bricks or other building blocks, and students should compete individually to build their tower in the least amount of time.

Explore more about automobile racing innovations using OnInnovation.com.

Name

Science, Life Skills and Innovations in American Automobile Racing
review/assessment questions

1. A race car is racing at the Indianapolis Motor Speedway. One lap at the speedway covers 2.5 miles.

   A How many laps would it take to complete the 500-mile race?

   B What would be the driver's average speed if he or she takes 2¾ hours to complete the race?

2. The Goldenrod Land Speed Racer once raced across the salt flats at 409 miles/hour. At that rate, how long would it take the racer to travel 100 miles?

3. Remembering the history of racing discussed in this unit, why do you think Henry Ford first built a race car and tried to win a race with it? Do you think his reason was similar or different from the reason many drivers offer today for wanting or needing to win?

4. Which of Newton's three laws of motion is best represented by each action described below?

   A In order to push a car forward, the man in the pits pushes his feet against the track, and the track pushes back.

   B A large heavy car is harder to push than a lighter car.

   C The driver suddenly hits the brakes of the car in which you are riding; your seat belt prevents your face from hitting the dash-board.

   D A race car runs out of gas and coasts long enough to get back to the pit area to refuel.

5. Use your knowledge from reading this unit on forces, motion and innovation to answer this question: Why do drivers and their engineers try to keep their race cars as lightweight as possible?

6. Make a sketch of a racetrack and show what part or parts of the track would need to be banked the most. Why?

6. (continued)

7. Why do race car drivers position their cars closely packed together in a long line while racing around the track?

8. If you were designing a wing or airfoil to take advantage of Bernoulli's principle, should the surface of the wing be longer over the top or longer over the bottom for each of the following cases?

A Flying an airplane

B Creating downforce from an oncoming wind

9. A NASCAR race car might go through 2 to 3 sets of tires during a race. Use terms from science and physics to explain why tires on a NASCAR racer can wear out so fast.

Science, Life Skills and Innovations in American Automobile Racing
review/assessment questions

1. A race car is racing at the Indianapolis Motor Speedway. One lap at the speedway covers 2.5 miles.

   A How many laps would it take to complete the 500-mile race?

   *500 miles * 1 lap/ 2.5 miles = 200 laps*

   B What would be the driver's average speed if he or she takes 2¾ hours to complete the race?

   *d= v * t*

   v = d / t = 500 miles / 2.75 hours = 181.81 miles/hour

2. The Goldenrod Land Speed Racer once raced across the salt flats at 409 miles/hour. At that rate, how long would it take the racer to travel 100 miles?

   *d = v * t*

   t = d / v = 100 miles/ 409 miles/hour = .244 hour

3. Remembering the history of racing discussed in this unit, why do you think Henry Ford first built a race car and tried to win a race with it? Do you think his reason was similar or different from the reason many drivers offer today for wanting or needing to win?

   Henry Ford wanted to get attention from sponsors so that they would invest money in his car company. Race car drivers today constantly need to win or perform well to attract sponsors.

4. Which of Newton's three laws of motion is best represented by each action described below?

A In order to push a car forward, the man in the pits pushes his feet against the track, and the track pushes back.

3rd law: A force in one direction will be equal and opposite to a force in the other direction

B A large heavy car is harder to push than a lighter car.

2nd law: force = mass times acceleration

C The driver suddenly hits the brakes of the car in which you are riding; your seat belt prevents your face from hitting the dashboard.

1st law: an object in motion will continue in motion

D A race car runs out of gas and coasts long enough to get back to the pit area to refuel.

1st law: an object in motion will continue in motion

5. Use your knowledge from reading this unit on forces, motion and innovation to answer this question: Why do drivers and their engineers try to keep their race cars as light as possible?

$F = ma$

A large mass means less acceleration but a lighter car (less mass) means more acceleration.

6. Make a sketch of a racetrack and show what part or parts of the track would need to be banked the most. Why?

The track needs to be banked the most in the tightest turns or corners. According to Newton's first law, cars tend to always continue in a straight line unless a force intervenes. If the track is curved, a force is necessary to turn the car around the curve and stay on the track. The force of the banked track helps the car turn instead of going straight.

7. Why do race car drivers position their cars closely packed together in a long line while racing around the track?

This configuration makes use of aerodynamic forces. The air goes over the top of the first car and then continues over all the cars in the row, making the cars in the back not have to fight the wind as much.

8. If you were designing a wing or airfoil to take advantage of Bernoulli's principle, should the surface of the wing be longer over the top or longer over the bottom for each of the following cases?

A Flying an airplane

An airplane wing needs to be longer on top, so the faster moving air above the wing causes a force upward to keep the airplane in the air.

B Creating downforce from an oncoming wind

A race driver wants downforce, so the bottom surface of an airfoil would be longer in order to produce a drop in pressure on its underside.

9. A NASCAR race car might go through 2 to 3 sets of tires during a race. Use terms from science and physics to explain why tires on a NASCAR racer can wear out so fast.

NASCAR race cars go around a lot of corners where the tires on the track need to provide a lot of force to keep the cars on the track. Because the tires do slide some when going around the curves, and because the tires get hot due to friction, they wear out rapidly.

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The Henry Ford sincerely thanks the following individuals who guided the development of the Transportation in America online Educator DigiKits.

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