grades
9-12

Physics, Technology and Engineering in
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

Amazing feats have been performed throughout the history of automobile racing: early racecars carried a rider on the running board; today, most racecar drivers survive crashes and walk away. In Physics, Technology and Engineering in Automobile Racing, use these events to explore with your students ***What physics concepts can be learned by analyzing automobile racing?*** Automobile racing is a vivid means of introducing physics concepts, including Newton's three laws of motion, forces in straight lines and circles, motion, distance, displacement, velocity, acceleration and momentum.

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

The Teacher Guide section includes resources to complement the *Physics, Technology and Engineering in Automobile Racing Unit Plan.* You will find a glossary, timeline, context-setting activities, 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. The lessons are organized so that the students can either work in class using handouts or, if the students have access to computers, view the lessons and digitized artifacts online at 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 America" collections. We hope you and your students will find these resources engaging and relevant.

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

contents

Please refer to the online version of the Educator DigiKits for the most updated links to digital artifacts.

teacher guide | for grades 9-12

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, under or around it.

Airfoil
A winglike device on a racecar 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.

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
The force toward the center that makes an object go 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
The 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 an object, or 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 racecar, 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 $KE = \frac{1}{2} m v^2$.

Mass
The amount of matter in an object.

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

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

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

Glossary Continued

Pressure
Force divided by area.

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

Revolution
The motion of one object as it orbits another object.

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

Rotational motion
The motion of an object turning on an axis.

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; work = force * distance, or $W = F d$.

Unit Plan Time Line

Racecars
from the Collections of **The Henry Ford**

1901 Ford "Sweepstakes" – Henry Ford's first racecar, 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 racecar, 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 racecar, driven by Dan Gurney and A. J. Foyt, which wins the 24 Hours of Le Mans.

1984 March 84C Cosworth Indianapolis racecar, driven by Tom Sneva; a typical Indianapolis racecar 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 race tracks.

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

1970s 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 Earnhart's death at the 2001 Daytona 500 shocks NASCAR and leads to its adoption of numerous safety devices.

Unit Plan Time Line 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,

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 *Physics, Technology and Engineering in Automobile Racing* Unit Plan or for a visit to **The Henry Ford.**

Pictures of Racecar Innovations

Ask students to find and bring in pictures of innovations in automobile racing cars. These pictures might be from the Internet, newspapers or magazines. Ask the students to explain why the innovations are important to both automobile race drivers and spectators. Discuss whether these innovations for automobile racing would also be appropriate to adopt for passenger cars and trucks.

Innovation Contest

Ask the students to each come up with an innovative idea of his or her own that might be incorporated into either a racecar or a passenger car. Encourage inventive and imaginative thinking. Tell the students that what may seem to be a ridiculous idea now might be developed into a workable idea later. Have the students explain their innovative ideas to the class, and let the class choose the best ideas.

Racecar Design Contest

Have the students design and build a racecar to roll down a ramp. All cars will roll down a 12-foot ramp that is elevated 1 or 2 feet at the starting end. The ramp should be 8 or 10 inches wide. Racecars must be home built; the material might be LEGO® bricks, balsa wood or some other building material. No car should be longer than 10 inches. The track may either have sides to keep the cars on the track or, to make it more challenging, not have sides. If the ramp does not have sides, then the car must stay on the track or ramp all the way down to qualify. To determine the winner, time each racecar individually over the same distance; the winner will be the car that makes it down the ramp in the least amount of time.

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Print

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Bisson, Terry. *Tradin' Paint: Raceway Rookies and Royalty*. St. Louis: San Val, 2001.

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

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

Friedman, David. *Pro Sports, Car Racing in America 1958-1974.* Osceola, WI: Motorbooks, 1999.

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

Offinowski, Stuart and Paul Offinowski. *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.

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

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

Online Teacher Resources

thehenryford.org
The official website 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 at its website, which includes web pages for Jim Hall's Chaparral Racing .

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

oninnovation.com
Oral histories, digitized artifacts, stories and content from some of today's most visionary thinkers and doers about what thinking and working like an innovator really means.

daytonainternationalspeedway.com
The official website for the Daytona 500 NASCAR race track.

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

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

si.edu
The official website of the Smithsonian Institution.

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

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

worldofoutlaws.com
The official website of the World of Outlaws motorsports sanctioning body.

scta-bni.org
The official website of the sanctioning body for the land speed racing meets at Bonneville Salt Flats, El Mirage, and Muroc.

Connections to National and Michigan Standards and Expectations

Michigan High School Content Expectations

Physics

P2.1A
Calculate the average speed of an object using the change of position and elapsed time.

P2.2A
Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.

P2.2D
State that uniform circular motion involves acceleration without a change in speed.

P2.3a
Describe and compare the motion of an object using different reference frames.

P3.1A
Identify the forces acting between objects in direct contact or at a distance.

P3.2A
Identify the magnitude and direction of everyday forces.

P3.2C
Calculate the net force acting on an object.

P3.3A
Identify the action and reaction force from everyday examples of force in everyday situations.

P3.3b
Predict how the change in velocity of a small mass compares with the change in velocity of a large mass.

P3.4A
Predict the change in motion of an object acted upon by several forces.

P3.4B
Identify forces acting on objects moving with constant velocity (e.g., cars on a highway.)

P3.4C
Solve problems involving force, mass, and acceleration in linear motion.

P3.4D
Identify forces acting on objects moving with uniform circular motion (e.g., cars on a circular track).

P3.4f
Calculate the changes in velocity of a thrown or hit object during and after the time it is acted on by the force.

P3.4g
Explain how the time of impact can affect the net force (e.g., air bags in cars, catching a ball).

P3.4g
Explain how the time of impact can affect the net force (e.g., air bags in cars).

P3.5a
Apply conservation of momentum to solve simple collision problems.

P4.1c
Explain why work has a more precise scientific meaning than the meaning of work in everyday language.

P4.1d
Calculate the amount of work done on an object that is moved from one position to another.

Continued...

P4.2A
Account for and represent energy transfer and transformation in complex processes (interactions).

P4.2B
Name devices that transform specific types of energy into other types of energy (e.g., a device that transformed electricity into motion).

P4.2D
Explain why all the stored energy in gasoline does not transform to mechanical energy of a vehicle.

P4.3C
Explain why all mechanical systems require an external energy source to maintain their motion.

P4.3d
Rank the amount of kinetic energy from highest to lowest of everyday examples of moving objects.

National Science Content Standards

Science as Inquiry

Understanding about Scientific Inquiry
- All students should develop abilities of technological design.
- All students should develop an understanding about science and technology.
- All students should understand that men and women made a variety of contributions throughout the history of science and technology.
- All students should gain an understanding of the history of science and technology.
- All students should understand that the desire to reduce risk often leads to new technology.
- All students should understand that the societal challenges often inspire questions which lead to scientific research and innovation.
- All students should be able to design a solution to a science or technological problem.
- All students should gain an understanding of technological discoveries.

Understanding Motion and Forces

- All students should understand that mathematics plays an essential role in science inquiry.
- All students should develop an understanding of motion and forces.

All students should understand that:
- The position of an object can be described by locating it relative to another object.
- An objects motion can be described by tracing and measuring its position over time.

All students should understand that:
- The position of objects can be changed by pushing or pulling.
- The motion of an object can be described by its position, direction and motion in space.
- An object that is not being subjected to a force will continue to move at a constant speed and in the same direction.
- Unbalanced forces will cause a change in speed or direction of an object's motion.
- All students should develop an understanding of the concept of rate.

Understanding of Energy and Energy Transformation

- All students should gain an understanding of energy and increases and disorder
- All students should gain an understanding the conservation of energy and matter.

Lesson 1
Analysis of Newton's Laws in Automobile Racing
Michigan High School Content Expectations

Physics

P2.3a
Describe and compare the motion of an object using different reference frames.

P3.1A
Identify the forces acting between objects in direct contact or at a distance.

P3.2A
Identify the magnitude and direction of everyday forces.

P3.2C
Calculate the net force acting on an object.

P3.3A
Identify the action and reaction force from everyday examples of force in everyday situations.

P3.3b
Predict how the change in velocity of a small mass compares with the change in velocity of a large mass.

P3.4A
Predict the change in motion of an object acted upon by several forces.

P3.4B
Identify forces acting on objects moving with constant velocity.

P3.4C
Solve problems involving force, mass, and acceleration in linear motion.

P3.4D
Identify forces acting on objects moving with uniform circular motion (e.g., cars on a circular track).

P3.4g
Explain how the time of impact can affect the net force (e.g., air bags in cars).

P3.5a
Apply conservation of momentum to solve simple collision problems.

Lesson 2 Forces in Automobile Racing
Michigan High School Content Expectations

Physics

P2.1A
Calculate the average speed of an object using the change of position and elapsed time.

P2.2A
Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.

P2.2D
State that uniform circular motion involves acceleration without a change in speed.

P3.2A
Identify the magnitude and direction of everyday forces.

P3.2C
Calculate the net force acting on an object.

P3.4A
Predict the change in motion of an object acted upon by several forces.

P3.4b
Identify forces acting on objects moving with constant velocity (e.g., cars on a highway).

P3.4D
Identify the forces acting upon objects moving with uniform circular motion (e.g., car on a circular track).

P3.dg
Explain how time of impact can affect the net force (e.g., air bags in cars.)

Lesson 3 The Study of Motion Using Artifacts from the Collections of The Henry Ford
Michigan High School Content Expectations

Physics

P2.1A
Calculate the average speed of an object using the change of position and elapsed time.

P2.2A
Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.

P2.2D
State that uniform circular motion involves acceleration without a change in speed.

P2.3a
Describe and compare the motion of an object using different reference frames.

P3.1A
Identify the forces acting between objects in direct contact or at a distance.

P3.2A
Identify the magnitude and direction of everyday forces.

P3.2C
Calculate the net force acting on an object.

P3.3A
Identify the action and reaction force from everyday examples of force in everyday situations.

P3.3b
Predict how the change in velocity of a small mass compares with the change in velocity of a large mass.

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Predict the change in motion of an object acted upon by several forces.

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Identify forces acting on objects moving with constant velocity (e.g., cars on a highway).

P3.4C
Solve problems involving force, mass, and acceleration in linear motion.

P3.4D
Identify forces acting on objects moving with uniform circular motion (e.g., cars on a circular track).

P3.4f
Calculate the changes in velocity of a thrown or hit object during and after the time it is acted on by the force.

P3.4g
Explain how the time of impact can affect the net force (e.g., air bags in cars, catching a ball).

Lesson 4 Ground Effects Innovations in Automobile Racing

Michigan High School Content Expectations

Physics

P2.1A
Calculate the average speed of an object using the change of position and elapsed time.

P2.2A
Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.

P2.2D
State that uniform circular motion involves acceleration without a change in speed.

P2.3a
Describe and compare the motion of an object using different reference frames.

P3.1A
Identify the forces acting between objects in direct contact or at a distance.

P3.2A
Identify the magnitude and direction of everyday forces.

P3.2C
Calculate the net force acting on an object.

P3.3A
Identify the action and reaction force from everyday examples of force in everyday situations.

P3.4A
Predict the change in motion of an object acted upon by several forces.

P3.4B
Identify forces acting on objects moving with constant velocity (e.g., cars on a highway).

P3.4C
Solve problems involving force, mass, and acceleration in linear motion.

P3.4D
Identify forces acting on objects moving with uniform circular motion (e.g., cars on a circular track).

Lesson 5
Work, Energy and Power in Automobile Racing

Michigan High School Content Expectations

Physics

P2.3a
Describe and compare the motion of an object using different reference frames.

P3.4f
Calculate the changes in velocity of a thrown or hit object during and after the time it is acted on by the force.

P3.4g
Explain how the time of impact can affect the net force (e.g., air bags in cars, catching a ball).

P3.4g
Explain how the time of impact can affect the net force (e.g., air bags in cars).

P3.5a
Apply conservation of momentum to solve simple collision problems.

P4.1c
Explain why work has a more precise scientific meaning than the meaning of work in everyday language.

P4.1d
Calculate the amount of work done on an object that is moved from one position to another.

P4.2A
Account for and represent energy transfer and transformation in complex processes (interactions).

P4.2B
Name devices that transform specific types of energy into other types of energy (e.g., a device that transformed electricity into motion).

P4.2D
Explain why all the stored energy in gasoline does not transform to mechanical energy of a vehicle.

Field Trip
Learning Enhancements

Classes are encouraged to take the following field trips to learn about physics, engineering, technology and automobile racing:

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
501 S College St.
Charlotte, NC 28202
nascarhall.com

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

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

unit plan | for grades 9-12

Physics, Technology and Engineering in Automobile Racing
Unit Plan Overview

Overarching Question

What physics concepts can be learned by analyzing automobile racing?

Key Concepts

- Acceleration
- Air resistance
- Force
- Friction
- Inertia
- Mass
- Momentum
- Safety features
- Speed
- Velocity
- Centripetal force
- Downforce
- Gravity
- Trade-off
- Acceleration due to gravity
- Conversion
- Displacement
- Distance
- Power
- Revolution
- Rotational motion
- Work

Key Concepts Continued

- Airfoil
- Bernoulli's principle
- Ground effect
- Pressure

Lessons and Main Ideas

Lesson 1
Analysis of Newton's Laws in Automobile Racing

- What are Newton's laws of motion, and how are they applied in automobile racing?

Lesson 2
Forces in Automobile Racing

- What forces are involved in automobile racing?
- How do air resistance and downforces from air movement create forces that affect racecars?
- What accounts for centripetal forces in automobile racing?

Lesson 3
The Study of Motion Using Artifacts from the Collections of **The Henry Ford**

- How are the basic concepts of distance, velocity, acceleration and inertia applied in the study of automobile racing?

Lesson 4
Ground Effects Innovations in Automobile Racing

- What are ground effects? How do they use physics principles? Why are they important for racecars?

Lesson 5
Work, Energy and Power in Automobile Racing

- How is energy transformed from one type to another in automobile racing?

Duration

5–10 class periods (45–60 minutes each)

Continued…

Unit Plan Overview Continued

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

Lesson 1
Analysis of Newton's Laws in Automobile Racing

- Willys Gasser, 1958 (side view ID# THF69391)
- 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
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446
- Lyn St. James Suited Up in Racecar, Giving a "Thumbs-Up", 2008 ID# THF58671
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024

Lesson 2
Forces 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
- Ford Race Car "666," 1906-1907, Driven by Frank Kulick ID# THF69468
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024
- Dave Lewis's Race Car Stopped on the Board Track at Altoona Speedway, Tipton, Pennsylvania, 1925 ID# THF73131
- March 84C Race Car, 1984 (cockpit view ID# THF69363)
- Leon Duray Being Timed at Culver City Speedway, California, 1927 ID# THF73132
- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (overhead view ID# THF69264)
- Race Car, "999" Built by Henry Ford, 1902 ID# THF70568

Lesson 3
The Study of Motion Using Artifacts from the Collections of **The Henry Ford**

- Barber-Warnock Special Race Car in Pit at Indianapolis Motor Speedway, 1924 ID# THF68329
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265) (side view ID# THF69258)

Continued…

Lesson 3 Continued

- Timing Slip From Oswego Dragway, Used with Buck & Thompson Slingshot Dragster, 1963 ID# THF45621
- Race Car, "999" Built by Henry Ford, 1902 ID# THF70568
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472

Lesson 4
Ground Effects Innovations in Automobile Racing

- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (aerial view ID# THF69264)
- March 84C Race Car, 1984 (aerial view ID# THF69371) (side view ID# THF69368)

Lesson 5
Work, Energy and Power in Automobile Racing

- Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)

Materials

- Computer with access to the Internet; digital projector and screen (preferred) OR printed handouts of the digitized artifacts and descriptions
- Background Information Sheet for Students #1A:Analysis of Newton's Laws and Racing
- Student Activity Sheet #1B: Newton's Laws
- Answer Key #1B: Newton's Laws
- Background Information Sheet for Students #2A: Forces in Automobile Racing
- Student Activity Sheet #2B: Forces
- Answer Key #2B: Forces
- Background Information Sheet for Students #3A: Study of Motion Using Artifacts from the Collections of **The Henry Ford**
- Student Activity Sheet #3B: Motion and Energy
- Answer Key #3B: Motion and Energy
- Background Information Sheet for Students #4A: Ground Effect Innovations in Automobile Racing
- Student Activity Sheet #4B: Ground Effect Innovations
- Answer Key #4B: Ground Effect Innovations
- Background Information Sheet for Students #5A: Work, Energy and Power in Automobile Racing
- Student Activity Sheet #5B: Work, Energy and Power
- Answer Key#5B: Work, Energy and Power
- Culminating Projects
- Extension Activities
- Student Activity Sheet #6: Review/Assessment Questions
- Answer Key #6: Review/Assessment Questions

Lesson 1 Analysis of Newton's Laws in Automobile Racing

Question for analysis

- What are Newton's laws of motion, and how are they applied in automobile racing?

Key concepts

- Acceleration
- Force
- Inertia
- Momentum
- Speed
- Air resistance
- Friction
- Mass
- Safety features
- Velocity

Digitized Artifacts

From the Collections of **The Henry Ford**

Lesson 1
Analysis of Newton's Laws in Automobile Racing

- Willys Gasser, 1958 (side view ID# THF69391)
- 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
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446
- Lyn St. James Suited Up in Racecar, Giving a "Thumbs-Up", 2008 ID# THF58671
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024

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 #1A: Analysis of Newton's Laws in Automobile Racing
- Student Activity Sheet #1B: Newton's Laws
- Answer Key #1B: Newton's Laws

Duration 1-2 class periods (45-60 minutes each)

Instructional Sequence

1. Distribute Background Information Sheet for Students #1A: Analysis of Newton's Laws in Automobile Racing. If possible, access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.
2. Use the Background Information Sheet to review, read and discuss with students the question for analysis, concepts, and information about Isaac Newton and his laws of motion as they apply to automobile racing.
3. Encourage students to make their own observations, ask questions and offer other examples from life that illustrate Newton's laws of motion.

Assessment

Assign Student Activity Sheet #1B: Newton's Laws to assess learning and understanding.

analysis of Newton's Laws in Automobile Racing

Question for Analysis

What are Newton's laws of motion, and how are they applied in automobile racing?

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 as the air 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.

Newton's 1st Law – The Law of Inertia

Newton's first law is called the law of inertia. Inertia is the resistance to change in motion. The first law states that a body at rest remains at rest and a body in motion remains in motion, unless the body is acted upon by an outside force. In everyday life, we have inertia because we tend to keep doing what we are already doing. When we are up, we like to stay up. But if we are sitting or sleeping, we like to stay sitting or sleeping.

In sports, we hear the term "momentum" used when one team gets going and just keeps on going. If a team has momentum, the team is difficult to stop.

If a car is standing still without the motor running, the car will remain there. Look at the digitized image of the Willys Gasser, 1958 (side view ID# THF69391).

Continued…

Newton's 1st Law – The Law of Inertia Continued

The Gasser will remain motionless until it is pushed by a force that accelerates it. The force could be provided by people [Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328] or by the car's engine.

Once a car is moving, it will remain moving. Look at the digitized image of a car that kept going straight instead of making the left hand turn [Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446].

When the driver starts the engine and pushes the accelerator, the motor produces a force that moves the car forward [Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472]. When the car accelerates forward, the driver and passengers feel as though they are thrown or pushed backwards, but actually the car goes forward while the driver and passengers remain where they are. They feel as though they are thrown backwards when the car seat hits them in the back.

Similarly, if a car is stationary and gets hit from the rear, the driver feels as if he or she is flying backwards. Actually, the car is pushed forward, leaving the driver behind.

Racecar drivers have high-backed seats so that when they accelerate forward, their entire body goes forward with the car [Lyn St. James Suited Up in Racecar, Giving a "Thumbs-Up", 2008 ID# THF58671]. Their heads do not snap back because they remain against the seat. In your family car, you have head rests and seats to keep you from feeling as though you are thrown backwards.

If a car is stopped by an outside force – for example, by crashing into another car or into a wall – its driver keeps on going. Safety belts help slow the driver to prevent him or her from flying out of the car or hitting the front windshield. The safety belts in racecars are called 5-point belts; they go around both the wearer's shoulders as well as his or her waist and attach at 5 points. In a passenger car, both safety belts and air bags are used to slow the driver and passenger.

Modern race drivers also use a device called a HANS device. The HANS device is a well-padded bar wrapped around the driver's neck to help protect the neck from flying side to side. During an accident, everything tends to fly around, staying in motion in whatever direction it was already headed. Some race drivers even have attachments to keep their hands attached to the steering wheel so that their hands and arms do not fly around during an accident.

Every car accident involves the concepts of Newton's first law. Safety features are devised to keep the driver (and the passengers, in passenger cars) from continuing forward against hard objects. To consider the great improvements in safety devices over the history of automobile racing, look at the picture of one of Henry Ford's early automobile races [Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024].

Compare the safety features in Ford's car with those in Lyn St. James's racecar [Lyn St. James Suited Up in Racecar, Giving a "Thumbs-Up", 2008 ID# THF58671]. Notice the safety features that help restrain the driver during an accident.

Continued…

Newton's 2nd Law – F = m a

Newton's second law can be stated as force equals mass times acceleration (F = m a). An unbalanced force will cause an acceleration, and the greater is the force, the greater will be the acceleration; conversely, 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? Innovative racecar designers want the most powerful engine possible in order to increase force and acceleration. At the same time, designers want the car to be lightweight in order to achieve better acceleration and speed. Look at the engine of the Ford Thunderbird NASCAR racecar [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)]. Engine size is regulated in most races, so designers or car builders cannot put too large an engine in their cars. Racecar builders try to make cars lighter by using aluminum or plastic rather than heavier steel, where possible. The mass of racecars has been a design problem that designers, engineers and racecar drivers have struggled with throughout the history of racing.

Notice the early racecar built by Henry Ford [Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024]. The 999 car had a large 1,150-cubic-inch engine to provide a large force for acceleration and speed.

Look at the picture of a racecar built for drag racing on a quarter-mile straight track [Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041]. The Slingshot car is very light. The formula used to calculate acceleration, a = F/m, shows that for a given force, a smaller mass means greater acceleration.

Working Problems Involving Newton's Laws

When working math problems involving Newton's second law, we always use kilograms (kg) for mass and meters per second^2 (m/sec^2) for acceleration. The metric unit of force is called a Newton (N), equal to 1 kilogram-meter/second^2.

Thus, a racecar with a mass of 900 kilograms accelerating at 10 meters/second every second (10 meters/second^2) requires a force of:

F = m a = 900 kg * 10m/sec2 = 9,000 Newtons

A force of 12,000 N will cause a car of mass 800 kilogram to accelerate at 15 meters/second^2:

A = F/m = 12,000 N / 800 kilogram = 15 m/sec^2

Net Force

When working F = m a problems, remember that it is net force that causes acceleration. A net force is the resultant force of two or more forces. A push of 200 Newtons to the left and a force of 80 Newtons to the right on a mass of 10.0 kilograms will result in a net force of 120 Newtons to the left. The net force is what is applied to an F = ma problem.

In this case, if the forces above are applied to a mass of 10 kilograms, the acceleration will be:

a = F/m = 120 N /10 kilogram = 12 meters/second^2

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 that for every force in one direction, there is an equal and opposite force in the other direction. During acceleration of a car, the motor and engine transfer force to the tires, which push against the pavement. The pavement pushes back on the racecar [Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024]. Forces cause objects to accelerate, so the car goes forward. Whenever two objects apply forces against each other, the lighter object moves faster and farther than does the heavier object. Thus the car moves rather than the track. If there is gravel or dirt on the track, then you see the gravel or dirt fly back as the car goes forward, because the gravel is lighter than the car.

To mathematically describe action and reaction, we use the formula m*v (left) = m*v (right). A 60 kilogram girl jumps to the left off a skateboard having a mass of 2 kilograms. If the girl goes left at 1 meter/second, how fast will the board fly?

60 kilograms * 1 meter/second (left) = 2 kilograms * v (right)

v(right) = 60 kg * 1 m/sec / 2 kg = 30 m/sec (right).

Another example of action and reaction is a jet plane in flight. The jet engines expel hot gases to the rear, and the jet is propelled forward. Another example is a runner pushing against the ground to run and the ground pushing back on the runner.

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Newton's Laws

Name ______________________

Formulas

$F = m a$ $a = \Delta v / \Delta t$ $v(f) = v(i) + a * t$

1. A racecar driver heads into a corner at 180 mph. As she goes into the corner, she slows down and rounds the curve to the left.
   A. What provides the force that allows her to make the curve?
   B. Using concepts from Newton's first law, discuss both its effects on the driver as she drives and how the driver safely handles those effects.

2. Three cars in different classes are drag racing. Car A has a mass of 800 kilograms. Car B has a mass of 1,000 kilograms. Car C, a large car, has a mass of 1,600 kilograms. If the three cars all have the same size engine with the same horsepower, what is the ratio of the accelerations of the 3 cars, A : B : C?

3. A racecar coming out of the pits accelerates from 0 meters/second to 60 meters/second in 8.0 seconds. If the mass of the racecar is 1,100 kilograms, what force does the engine provide?

4. For each of the descriptions below indicate which of Newton's Law most applies.
   1st law law of inertia
   2nd law F = m a
   3rd law action and reaction

   A ______ During a racing accident, a wheel comes off a car and flies down the track and up against the fence.

   B ______ Racecar designers have been known to try to take every possible pound of weight off the racecar they are designing.

   C ______ If a car is rammed from behind, the driver of the car in front feels as though he is thrown backwards.

   D ______ A racecar on a dirt track throws rocks and dirt backwards as the driver attempts to accelerate.

   E ______ An engineer for a new racecar discovers a better shape for the front of the car to make the car even more aerodynamic.

Newton's Laws

1. A racecar driver heads into a corner at 180 mph. As she goes into the corner, she slows down and rounds the curve to the left.

A. What provides the force that allows her to make the curve?

Friction between the tires and the pavement provides the inward force necessary for a car to stay on the curve in a track. Modern racecar drivers go through several sets of tires as the tires wear out rapidly.

B. Using concepts from Newton's first law, discuss both its effects on the car and the driver as she drives and how the driver safely handles those effects.

Newton's first law states that an object at rest remains at rest and an object in motion remains at that motion unless acted upon by an outside force.

Examples of the effects on the car and driver and how he or she safely handles situations:

- *The cars travel at a high rate of speed, usually very close together. Because the cars are not moving very fast relative to each other, this usually does not cause problems.*
- *The drivers use a 5-point belt system to stay secure during an accident or rapid braking as, according to the first law, the driver tends to keep moving when the car stops and the belt slows the driver's movement, preventing injury.*
- *The drivers use a HANS device that wraps around their necks and heads to keep their heads from being thrown around (especially sideways) during sudden acceleration or decelerations.*
- *The tires need to grip the road during acceleration in order to push back against the track as the car is propelled forward.*

Continued...

2. Three cars in different classes are drag racing. Car A has a mass of 800 kilograms. Car B has a mass of 1,000 kilograms. Car C, a large car, has a mass of 1,600 kilograms. If the three cars all have the same size engine with the same horsepower, what is the ratio of the accelerations of the 3 cars, A : B : C?

Larger mass means lower acceleration. The ratio of the acceleration is inverse to the ratio of the masses, so A(8): B(5): C(4)

3. A racecar coming out of the pits accelerates from 0 meters/second to 60 meters/second in 8.0 seconds. If the mass of the racecar is 1,100 kilograms, what force does the engine provide?

$a = \Delta v / \Delta t$

a = 60 meters/second / 8.0 seconds = 7.5 meters/second^2

*F = ma = 1,100 kilograms * 7.5 meters/second^2 = 75,000 Joules provided by the engine.*

4. For each of the descriptions below indicate which of Newton's law most applies.

1st law law of inertia
2nd law F = m a
3rd law action and reaction

A 1st During a racing accident, a wheel comes off a car and flies down the track and up against the fence.

B 2nd Racecar designers have been known to try to take every possible pound of weight off the racecar they are designing.

C 1st If a car is rammed from behind, the driver of the car in front feels as though he is thrown backwards.

D 3rd A racecar on a dirt track throws rocks and dirt backwards as the driver attempts to accelerate.

E 2nd An engineer for a new racecar discovers a better shape for the front of the car to make the car even more aerodynamic.

Lesson 2 Forces in Automobile Racing

Question for analysis

- What forces are involved in automobile racing?
- How do air resistance and downforces from air movement create forces that affect racecars?
- What accounts for centripetal forces in automobile racing?

Key concepts

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

Digitized Artifacts

From the Collections of **The Henry Ford**

Lesson 2
Forces 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
- Ford Race Car “666,” 1906-1907, Driven by Frank Kulick ID# THF69468
- Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041
- Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024
- Dave Lewis’s Race Car Stopped on the Board Track at Altoona Speedway, Tipton, Pennsylvania, 1925 ID# THF73131
- March 84C Race Car, 1984 (cockpit view ID# THF69363)
- Leon Duray Being Timed at Culver City Speedway, California, 1927 ID# THF73132
- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (overhead view ID# THF69264)
- Race Car, “999” Built by Henry Ford, 1902 ID# THF70568

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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: Forces in Automobile Racing
- Student Activity Sheet #2B: Forces
- Answer Key #2B: Forces

Instructional Sequence

1. Distribute copies of Background Information Sheet for Students #2A: Forces in Automobile Racing to read and study. If possible, access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.
2. Use the Background Information Sheet to review, read and discuss with students the questions for analysis, concepts and information about forces as they apply to automobile racing.
3. Encourage students to make their own observations, ask questions and offer other examples from life that illustrate the concept of forces in everyday life

Assessment

Have the students complete Student Activity Sheet #2B: Forces to assess their learning and understanding.

forces in Automobile Racing

Questions for Analysis

- What forces are involved in automobile racing?
- How do air resistance and downforces from air movement create forces that affect racecars?
- What accounts for centripetal forces in automobile racing?

Key Concepts

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

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

Centripetal Force
The force toward the center that makes an object go in a circle rather than in a straight line.

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

force
Any push or pull.

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.

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

Mass
The amount of matter in an object.

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

The Concept of Force

In simple terms, a force is any push or pull. We encounter numerous types of forces every day. Many of these forces can be analyzed using examples from automobile racing.

An unbalanced force will make an object increase or decrease its speed, while forces that are balanced do not cause acceleration. A racecar sitting on the track is subject to forces, but they are balanced [Soap Box Derby Car, 1939 ID# THF69252]. The force of gravity pulls down on the car while an equal force from the track pushes back up so that the forces are balanced and the car remains stationary. When the soapbox derby car is on a hill, the downward force is greater than the upward force, and the car accelerates down the hill.

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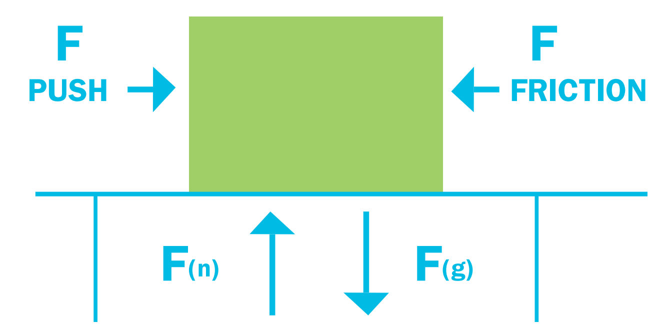
Free-Body Diagrams

When analyzing forces, a useful concept is a free-body diagram. A free-body diagram is a simple sketch with arrows that show the direction of all the forces. Longer arrows represent larger forces and shorter arrows represent smaller forces. Using free-body diagrams helps scientists visualize all the forces.

Below is a simple free-body diagram for a block on a table; the block is being pushed to the right. F(n), which is the upward force from the table, is called a normal force. F(g) is the force of gravity.



There are many forces involved in an automobile race, and free-body diagrams can help to show them.

Accelerating Forces

Before a race, when a racecar's engine hasn't been started to provide a forward force for acceleration, the car is sitting still at the starting line [Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472].

In order to move an object, there must be an unbalanced force. Notice that it takes several people to push a car and overcome friction (a backwards force opposing motion) to get the car to accelerate [Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328]. For safety reasons, people in the pit areas usually push racecars by hand before races, as the pit areas are crowded with workers and spectators.

It takes a lot of force to accelerate a large racecar. In one of the earliest racecars built by Henry Ford, the motor was extremely large to provide a lot of force. Because the motor and the rest of the car were so massive, this early car could only race at about 90 miles per hour [Ford Race Car "666," 1906-1907, Driven by Frank Kulick ID# THF69468]. The car was effective for its day because other cars were also very heavy. Compare Ford's car to the 1960 Slingshot dragster, which has a smaller engine but is much lighter, enabling it to go faster than the 666 [Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041].

In math terms, the formula that describes accelerating forces is $F = m a$. For a given mass, a larger value for force will create more acceleration. A smaller mass would also create more acceleration. If the force on a car is tripled and the mass is cut in half, the acceleration would be 3 * 2 times the acceleration, or 6 times the acceleration. Doubling the force but also doubling the mass will keep the acceleration the same. (2 * F gives 2 times the acceleration and 2 * m gives ½ the acceleration, so overall the acceleration would be the same.)

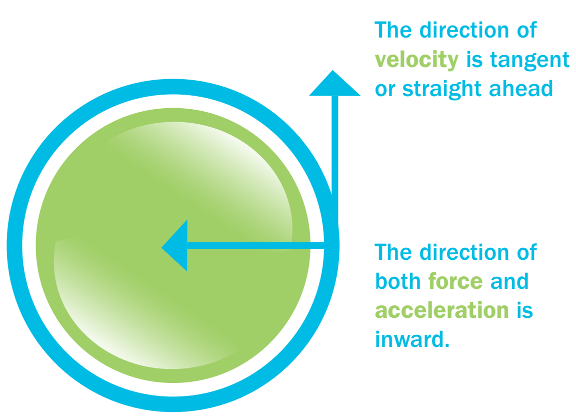
Centripetal Force

Another force involved in racing is centripetal force. Newton's first law states that a body in motion remains in motion unless acted upon by an outside force. A centripetal force is any force that pulls the car back toward the center of the circle or curve that the car is traveling in. Some race tracks are banked to "push" the car back toward the center with an inward force.

Continued…

Most people think that when a car is traveling around a curve, the car is forced out of the circle. Actually, a car's natural motion will keep it going straight, but there has to be an inward force toward the center to keep the car on the track [Damaged Race Car After a Racing Accident, 1905-1915 ID# THF12446]. In this digital image, the car has crashed through the fence. If you look back at the track in upper left, you can see that the car was coming into a left-hand curve but didn't make the curve. In order to stay on the track around the curve, the car needed an inward force. The tires against the road or pavement normally provide the inward force in a circle, but in this case, for some unknown reason, the tires did not force the car back inwards.

A helpful diagram shows the directions of force, acceleration and velocity for an object traveling in a circle or curve:



Look at the digital image of the driver in the driver's seat and a man sitting on the running board on the left side of the car [Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024]. What do you think the man on the running board is doing?

This is actually Henry Ford driving, with his friend Spider Huff riding on the side. Imagine sitting on the small running board, racing and bouncing down the road at 60 to 90 miles per hour.

Newton's first law states that an object (in this image, a car) in motion will continue in motion (straight ahead) unless acted upon by a force to change either the speed or direction of motion). When a driver makes a left hand turn, his racecar keeps trying to go straight. The car's tires grip the road to provide a force to turn the car around the corner or circle. In early racecars, the bottom of the car where the tires are located turned with the tires, but the heavy top of the car tried to keep on going straight. Early cars were unstable, so when they rounded a left-hand turn they tended to roll over to the right if they were going very fast.

So why did the rider ride on the left side? Most races are on oval tracks where the drivers are almost constantly turning left around curves. Since early racecars on these tracks could not corner very fast without rolling over to the right, the weight of the running-board rider on the left provided a downforce on the left side of the car to keep it balanced.

Notice the similarity to sailboat racers who lean over the edge of their sailboat to keep it from tipping over.

Many race tracks are banked to provide more centripetal force. The larger the angle of the banked turns, the faster the racecar can travel around the curve. The banked turn allows the tires to grip better and gain more traction [Leon Duray Being Timed at Culver City Speedway, California, 1927 ID# THF73132].

The formula for centripetal force is F = m v2 / r. The m is mass, the v is velocity and r is the radius of the curve (if you continue the curve to make it a complete circle, r is the imaginary radius of that imaginary circle).

Continued…

Example Problem

A car with a mass of 800 kilograms is traveling at a speed of 160 miles/ hour (about 72 meters/second) around a curve with an imaginary radius of 100 meters. Find the force needed by the tires or track to keep the car in a circle.

F = m * v2 / r = 800 kilograms * (72 meters/second) 2 / 100 meters = 41,470 Newtons (N) of force.

Center of Gravity

Lowering the center of gravity or center of weight of a car also helps keep it from rolling over. Most of the weight in modern racecars is very low to the ground, giving them what is called a low center of gravity. The center of gravity of an object is the average center of all its weight. If a car's center of gravity is too high, it can tip over while going around sharp turns.

Maintaining Racecars

The running-board rider on early racecars also provided another service. Can you guess what that might be? The rider watched the engine to make certain that it was running properly and could warn the driver to slow down if there was an engine or gear problem. If needed, he could actually oil the motor during the race. He was also looking around, especially behind the driver, to help avoid accidents. The running-board rider is certainly an example of an early innovation in racing.

In modern racecars, onboard computers monitor the car's entire system and send information back to the engineers in the pits so that necessary adjustments and repairs can be made to the car during pit stops. Look at the image of an older pit stop during a car race and compare it with what you've seen in modern NASCAR races [Dave Lewis's Race Car Stopped on the Board Track at Altoona Speedway, Tipton, Pennsylvania, 1925 ID# THF73131].

G-Forces

Sometimes, scientists refer to large forces as g-forces. One g-force is the normal force of gravity on a person or object, which is the same as the weight of the person or object. Thus, one g-force is equal to mass times gravity. To find a person's weight, or the force of gravity on that person, multiply the person's mass by the acceleration due to the earth's gravity, a value of 9.8 $meters/second^2$. If a force measures 4 times the calculated force of gravity, this force would be called four gs. In the example problem above, the 800-kilogram car would have a weight, or one g, of 800 kg * 9.8 m^2 = 7,840 N.

In this case, the calculated force going around the curve would be 41,470 Newtons. The 41,470 N would be 41,470 N /7,840 N or about 5.3 gs, and the racecar driver would feel about 5 times his normal body weight while going around the curve. Because racecar drivers constantly feel the sensation of several gs, they need to be in very good physical condition.

Forces on Tires and Tire Design

Because the force between the tires and the road needs to be so large, tires wear out rapidly. Look at the width of the tires on a newer racecar [March 84C Race Car, 1984 (cockpit view ID# THF69363)] and compare them with the tires on an early racecar [Race Car, "999" Built by Henry Ford, 1902 ID# THF70568]. Physicists usually say that the width of the tire shouldn't provide for friction force, but engineers have found that the wide tires work best, gripping better and lasting longer.

Continued…

Drag Force, or Air Resistance Force

Innovators are constantly redesigning cars to cut down on wind resistance by reshaping the front of the car. Look at Willys Gasser, 1958 (front view ID# THF69394). This car certainly fights the force of air resistance; it has to push through the air. The force of the air slows the acceleration and speed of the car, so 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 shape of the Ford Thunderbird [Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (overhead view ID# THF69264)]. The front of the Gasser pushed a lot of air, but the Thunderbird has a sloped front, allowing air to pass over the top of the car with less back 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.

Engineers do everything they can to cut down on air drag, or the force of air resistance, in order to gain more speed. In a passenger car, the shape of the car is aerodynamically designed with a sloping front to allow the car to pass through the air with less force and therefore get better gas mileage. Modern passenger cars are wind-tunnel tested to make certain that they will not encounter too much air resistance, or drag.

Name

Forces

1. Draw a free-body diagram for a racecar rounding a curve during a race.

2. Explain the physics of force, mass and acceleration for a NASCAR racecar coming out of the pits.

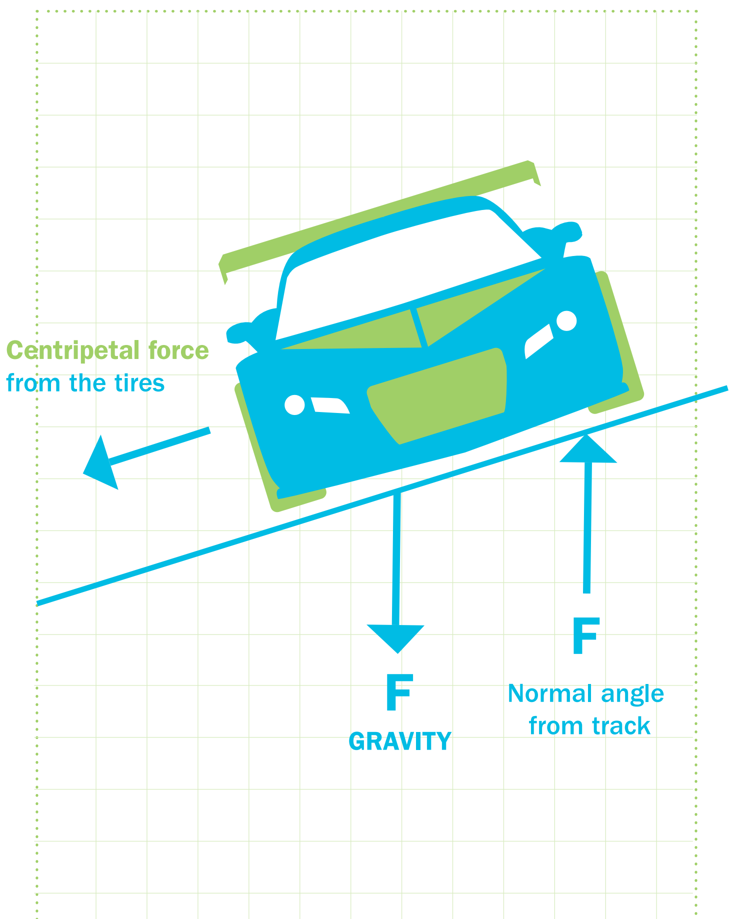
3. How much force would be needed to for a 900-kilogram racecar to accelerate from 0 meters/second to 65 meters/second in 10 seconds?

4. A small, fairly light drag racecar accelerates from the starting line at a high rate of speed of speed. Later, a different car, having 3 times as much mass but with an engine that delivers 4 times the force, takes its turn. What is the acceleration of the second car compared to the first car?

5. A force of 100 N (Newtons) is applied toward the left on a 6-kilogram block on a rough floor having a friction force of 30 N. A second force is applied to the brick toward the right at 50 N. What is the magnitude and direction of the net force on the block?

Forces

1. Draw a free-body diagram for a racecar rounding a curve during a race.



2. Explain the physics of force, mass and acceleration for a NASCAR racecar coming out of the pits.

As a NASCAR car comes out of the pits, the pit crew exerts a quick small force as they push the car. The engine provides a large force that is transferred to the tires. The car begins to accelerate according to a = F / m, (the larger the mass, the less the acceleration, the larger the force the more the acceleration). The driver turns the steering wheel, causing a force to change the direction of the car through the tires.

3. How much force would be needed for a 900-kilogram racecar to accelerate from 0 meters/second to 65 meters/second in 10 seconds?

$F = ma = m * \Delta v / \Delta t$

$F = ma = 900$ kilograms $* (65$ meters/second $- 0$ meters/second$)/10$ seconds $= 5850$ N.

Continued...

4. A small, fairly light drag racecar accelerates from the starting line at a high rate of speed. Later, a different car, having 3 times as much mass but with an engine that delivers 4 times the force, takes its turn. What is the acceleration of the second car compared to the first car?

3 times as much mass means 1/3 as much acceleration, and 4 times the force means 4 times the acceleration. Therefore the ratio of acceleration of Car 2 to Car 1 is 4:3.

5. A force of 100 N (Newtons) is applied toward the left on a 6-kilogram block on a rough floor having a friction force of 30 N. A second force is applied to the brick toward the right at 50 N. What is the magnitude and direction of the net force on the block?

Net force =

100 N left – 50 N right – 30 N friction = 20 N net

F = ma

a = F(net) / m = 20 Newtons /6 kilogram = 3.33 Newtons

Lesson 3 The Study of Motion Using Artifacts from the Collections of **The Henry Ford**

Question for analysis

How are the basic concepts of distance, velocity, acceleration and inertia applied in the study of automobile racing?

Key concepts

- Acceleration
- Acceleration of Gravity
- Centripetal Force
- Conversions
- Displacement
- Distance
- Force
- Friction
- Inertia
- Mass
- Speed
- Velocity
- Power
- Revolution
- Rotational motion
- Work

Digitized Artifacts

From the Collections of **The Henry Ford**

Lesson 3
The Study of Motion Using Artifacts from the Collections of **The Henry Ford**

- Barber-Warnock Special Race Car in Pit at Indianapolis Motor Speedway, 1924 ID# THF68329
- Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265) (side view ID# THF69258)
- Timing Slip From Oswego Dragway, Used with Buck & Thompson Slingshot Dragster, 1963 ID# THF45621
- Race Car, "999" Built by Henry Ford, 1902 ID# THF70568
- Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472

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: The Study of Motion Using Artifacts from the Collections of **The Henry Ford**

– Student Activity Sheet #3B: Motion and Energy

– Answer Key #3B: Motion and Energy

Instructional Sequence

1 Distribute copies of the Background Information Sheet for Students #3A: The Study of Motion Using Artifacts from the Collections of The Henry Ford to read and study. If possible, access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.

2 Use the Background Information Sheet to review, read and discuss with students the question for analysis and concepts and information about distance, velocity and acceleration as they apply to automobile racing.

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

4 Follow up with discussions on velocity, speed, distance, displacement, acceleration and relative motion.

Assessment

Ask the students to complete Student Activity Sheet #3B: Motion and Energy to assess their learning and understanding.

study of motion
Using Artifacts from the Collections of **The Henry Ford**

Question for Analysis

How are the basic concepts of distance, velocity, acceleration and inertia applied in the study of automobile racing?

Key Concepts

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

Acceleration of gravity
The acceleration downward, due to gravitational attraction, of a falling body.

Centripetal force
The force toward the center that makes an object go 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.

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.

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

Velocity
The speed of an object including the direction of an object.

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

Revolution
The motion of one object as it orbits another object.

Rotational motion
The motion of an object turning on an axis.

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.

Continued...

Early Automobile Racing

Compared to races today, most early automobile races were short. Early racecars were still far from reliable and were very much in the development stage.

In the earliest races, a rider rode on the running board to constantly oil the gears and keep the motor lubricated. Pit stops were quite different; mechanics had to make many adjustments and repairs. Look at this image of a pit crew working with no particular hurry on a car during a race [Barber-Warnock Special Race Car in Pit at Indianapolis Motor Speedway, 1924 ID# THF68329].

Henry Ford became interested in developing racecars largely to showcase his talents at building cars in order to attract investors to his new Ford Motor Company. Look at the digitized composite photograph depicting Henry Ford driving the 999 racecar [Henry Ford Driving the 999 Race Car Against Harkness at Grosse Pointe Racetrack, 1903 ID# THF23024]. Driving this car in practice runs, Henry Ford completed a one-mile lap of the Grosse Pointe track in one minute and eight seconds. Can you determine his average speed for this lap

Conversions

Probably the most confusing aspect of working problems about automobile racing is that some measurements are given in the English System, which uses miles and miles per hour, and other measurements are given in the International System of Units (SI), which uses meters and joules and kilograms. When working problems using any math or physics equations, be certain that all units are from the same system, either English or SI. Units of length should be all in miles for the English system, or all in kilometers or all in meters for the International system. Times must all be in hours or seconds (for either system) and mass must be in kilograms for the International system. Speed must be in meters per second (m/s) or kilometers per hour (km/hr) for the International system or miles per hour (mi/hr) for the English system.

Sample Conversion Problems

To convert all values to the same units, multiply by an appropriate factor that is equal to 1. Either of the equivalent units can be numerator or denominator to cancel units. Examples:

Convert 25 minutes to seconds

$$25 \text{ minutes} * \frac{60 \text{ seconds}}{1 \text{ minute}} = 1{,}500 \text{ seconds}$$

Convert 6 miles to meters

$$6 \text{ miles} * \frac{1{,}610 \text{ meters}}{1 \text{ mile}} = 9{,}660 \text{ meters}$$

Convert 120 miles/hour to meters/second

$$\frac{120 \text{ miles}}{\text{hour}} * \frac{1{,}610 \text{ meters}}{\text{miles}} * \frac{1 \text{ hour}}{3{,}600 \text{ seconds}} = 53.7 \text{ meters/second}$$

Referring to the early racecar above, we can now calculate the average speed for the 10-mile race that took 1 hour 10 minutes:

First convert the 10 minutes to hours

$$10 \text{ minutes} * \frac{1 \text{ hour}}{60 \text{ minutes}} = 0.17 \text{ hour}$$

speed = distance/time = 10 miles/1.17 hours = 8.55 miles/hour

Calculating Distance, Speed and Velocity

In correct physics terms, distance and displacement have different meanings. Distance is simply the difference between two points, $d = x(2) – x(1)$ where $x(2)$ is the ending or second point and $x(1)$ is the beginning or 1st point. Displacement, however, is the distance and the direction from the origin. If you walk 8.0 meters north,

Continued…

8.0 meters east, and 8.0 meters south, your distance will be 24 meters but your displacement will be 8.0 meters east of the origin.

In the same way, speed and velocity have different meanings. Speed is the distance traveled per time. Velocity is the displacement per time. A velocity calculation for 8.0 meters north, 8.0 meters east and 8.0 meters south for a trip lasting 4.0 seconds would be:

v = d / t = 8 meters/ 4 second = 2 meters/second east

For most physics problems, we interchange the words speed and velocity, and most people do not differentiate between the two.

There are several basic equations that are useful in physics and that can be helpful when analyzing automobile racing:

Physics Equations of Motion

1. $d = v(\text{average}) * t$
2. $v(\text{average}) = \text{total distance} / \text{total time}$
3. $a = \Delta v / \Delta t$ (where Δv means change in velocity and Δt means change in time)
4. $v(\text{average}) = \frac{v(\text{initial}) + v(\text{final})}{2}$ (v(i) means initial velocity and v(f) means final velocity
5. $d = v(i) * t + ½ * a * t^2$
6. $v(f)^2 + v(i)^2 + 2 a * d$
7. Kinetic energy $KE = ½ m * v^2$
8. Potential energy of gravity $PE = m * g * h$
9. Work $W = F * d$
10. Centripetal force $F = \frac{m * v^2}{R}$

Sample Motion Problems

1. A car starts from rest and accelerates to a speed of 140 miles per hour over a 10-second period. What is the car's acceleration?

   $A = \Delta v / \Delta t = 140$ miles/hour /10 seconds = 14 miles/hour per second, so the car gains 14 miles per hour each second.

   If we want the acceleration in meters/second^2, we first need to convert miles/hour to meters/second:

   $$\frac{140 \text{ miles}}{\text{hour}} * \frac{1{,}610 \text{ meters}}{\text{miles}} * \frac{1 \text{ hour}}{3{,}600 \text{ seconds}} = 62.6 \text{ meters/second}^2$$

   Acceleration =
   62.6 meters/second /10 seconds = 6.26 meters/second^2

2. Because of a refueling problem at the Daytona 500, a car took 2 seconds longer in the pits than did its competitor. At an average racing speed of 170 miles/hour, what distance, in feet, did the car lose to its competitor?

   $D = v * t =$

   $$\frac{170 \text{ miles}}{\text{hour}} * \frac{5{,}280 \text{ feet}}{\text{mile}} * \frac{1 \text{ hour}}{3{,}600 \text{ seconds}} * 2 \text{ seconds} =$$

   499 feet, or almost 166 yards

   (No wonder pit crews work with such organization so rapidly!)

Analyzing Energy

The various kinds of energy are another interesting aspect of automobile racing. In a car, the chemical energy of the fuel becomes thermal energy in the engine. Look at the digitized image of the engine in the red Thunderbird #9 [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265) (side view ID# THF69258)]. The thermal energy in the engine then becomes kinetic energy, or energy of motion, as the car races around the track.

Continued…

To analyze a drag race, determine the kinetic energy gained by a car during a quarter mile. Look at this image of the start of a drag race [Official Start of First NHRA Drag Racing Meet, Great Bend, Kansas, 1955 ID# THF34472]. At the start of the race, the car's speed is obviously 0 mph. At the completion of a drag race, the racer is typically given a timing slip like this one from the Oswego Dragway [Timing Slip From Oswego Dragway, Used with Buck & Thompson Slingshot Dragster, 1963 ID# THF45621].

Note the top speed measured is 123.29 mph which lasted 11.32 seconds.

While we do not have the means to calculate the chemical energy used, we can calculate the kinetic energy gained by the racecar during the 11.32 seconds. We can also calculate the average force the engine provided during the race.

We will assume the weight of the car was 1600 pounds, or about 700 kilograms. First, convert the 123.29 miles/hour to meters/second, as kinetic energy needs to be measured in kilograms, meters and seconds to get the proper energy unit of joules.

$$\frac{123.29 \text{ miles}}{\text{hour}} * \frac{1{,}610 \text{ meters}}{\text{miles}} * \frac{1 \text{ hour}}{3{,}600 \text{ seconds}} = 55.14 \text{ meters/second}$$

Next, calculate the kinetic energy

KE = ½ m * v^2 = ½ * 700 kilogram * (55.14 meters/second)^2 = 1.06 x 106 joules

The kinetic energy gained = the work done by the engine.

In a quarter mile, the KE gained = Work = Force * distance.

Convert the quarter mile to meters

¼ mile * 1,610 meters/mile = 402.5 meters

Calculate the kinetic energy and the work

KE = 1.06 x 106 joules = Work = F * 402.5 meters

The force supplied by the engine is therefore

W / d = 1.06 x 106 joules / 402.5 meters = 2,633 Newtons of force

Rotational Motion

There are many examples of rotational motion in automobile racing. The wheels turn hundreds of revolutions through the course of a race. The motor itself rotates in what is referred to as revolutions per minute, or rpm. Each time a tire rotates through one revolution, the car moves the distance equal to the circumference of the tire. The distance a car moves with each revolution of a tire can be calculated from the equation

distance = Circumference = 2πr

where r is the radius of the tire; a 15-inch tire means its radius is 15 inches. So each time the tire rotates one revolution, the car moves

C = 2πr = 2 π * 15 inches = 94.2 inches * 1 foot /12 inches = 7.85 feet

A larger tire would theoretically allow a racecar to travel faster or farther in one revolution. A large tire, however, has less power, so that large tires are not practical. (In most races, to keep everything competitive all the racecars must have the same size tires.) Tires on early racecars were fairly large as can be seen in the old Ford # 999 car [Race Car, "999" Built by Henry Ford, 1902 ID# THF70568]. Compare the tires on the 999 with the tires on a NASCAR racecar [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (side view ID# THF69258)].

Name ______________________

motion and Energy

Formulas

d =v * t

t = d / v

a = Δ v / Δ t

v(f) = v(i) + a * t

d = v (ave) * t

v (ave) = d(total) / t(total)

F = m*a

d = v(i) *t + ½ a * t^2

$v(f)^2$ = $v(i)^2$ + 2 * a * d

Conversions

1 mi = 1,610 m

1 hr = 3,600 sec

1 kilogram = 2.2 lbs

100 cm = 1.00 m

1. Car A is traveling 190 mph and Car B, traveling slower, is racing at 180 mph. How many more seconds will it take Car B than Car A to travel one lap of the 2.5 mile track?

2. In a car race in the early 1900s, a car averaged 65 mph for the 30 laps of the 1.5 mile track. How long did it take the car to complete the race?

3. In a race in the early 1900s, the pit crew took 10 minutes to get a Car A ready to head back onto the track. If the lead car is traveling at 50 mph, what distance would the lead Car B travel while the pit crew worked on Car A?

4. A drag racecar travels the quarter mile (402 meters) increasing its velocity from 0 meters/second to 60 meters/second. Calculate its acceleration.

5. What would be the average velocity of an Indianapolis 500 racecar if it takes 2 hours and 40 minutes to complete the 500 miles of the Indianapolis race?

6. A racecar is traveling at 35 meters/second during a yellow-flag caution lap. When the green flag is dropped to continue the race, how long will it take to get up to 86 meters/second if the car can accelerate at 6 meters/second^2?

motion and Energy

1. Car A is traveling 190 mph and Car B, traveling slower, is racing at 180 mph. How many more seconds will it take Car B than Car A to travel one lap of the 2.5 mile track?

*d = v * t or t = d / v*
Car A) t = d/v =2.5 miles /190 mph = .01316 hour
Car B) t = 2.5 miles /180 mph = .01389 hour
Time difference = .01389 hr - .01316hr = .00073 hr
*.00073 hr * 3,600 sec/ hr = 2.263 seconds*
Car A wins.

2. In a car race in the early 1900s, a car averaged 65 mph for the 30 laps of the 1.5 mile track. How long did it take the car to complete the race?

*d = 30 laps * 1.5 mile/lap = 45 miles*
*t = d / v = 45 miles / 65 mph = .692 hr * 60 min/ hr = 41.5 minutes*

3. In a race in the early 1900s, the pit crew took 10 minutes to get a Car A ready to head back onto the track. If the lead car is traveling at 50 mph, what distance would the lead Car B travel while the pit crew worked on Car A?

*d = v * t = 50 mph * 10 min * 1hr /60 min = 8.3 miles*

4. A drag racecar travels the quarter mile (402 meters) increasing its velocity from 0 meters/second to 60 meters/second. Calculate its acceleration.

$v(f)^2 = v(i)^2 + 2 * a * d$
$(60\ m/sec)^2 = 0 + 2 * a * 402\ m$; therefore $a = (60\ m/sec)^2 / (2 * 402\ m) = 4.48$ meters /second^2

5. What would be the average velocity of an Indianapolis 500 racecar if it takes 2 hours and 40 minutes to complete the 500 miles of the Indianapolis race?

v(ave) = d(total) / t(total) =
500 miles/2.67 hours = 187.3 mph

6. A racecar is traveling at 35 meters/second during a yellow-flag caution lap. When the green flag is dropped to continue the race, how long will it take to get up to 86 meters/second if the car can accelerate at 6 meters/second^2?

$a = \Delta v / \Delta t$
$\Delta v / a = \Delta t = (86\ m/sec - 35\ m/sec) / 6\ m/sec^2 = 8.5$ seconds

Lesson 4 Ground Effects Innovations in Automobile Racing

Question for analysis

What are ground effects? How do they use physics principles? Why are they important for racecars?

Key concepts

- Airfoil
- Bernoulli's principle
- Downforce
- Ground effect
- Pressure

Digitized Artifacts

From the Collections of **The Henry Ford**

Lesson 4
Ground Effects Innovations in Automobile Racing

- Willys Gasser, 1958 (front view ID# THF69394)
- Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (aerial view ID# THF69264)
- March 84C Race Car, 1984 (aerial view ID# THF69371) (side view ID# THF69368)

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
- Background Information Sheet for Students #4A: Ground Effect Innovations in Automobile Racing
- Student Activity Sheet #4B: Ground Effects Innovations
- Answer Key #4B: Ground Effects Innovations

Duration 1-2 class periods (45-60 minutes each)

Instructional Sequence

1. Introduce the concepts of aerodynamics, air movement and forces.
2. Distribute copies of Background Information Sheet for Students #4A: Ground Effects Innovations in Automobile Racing. If possible access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.
3. Use the Background Information Sheet to review, read and discuss with students the questions for analysis, concepts and information about aerodynamics, air movement and forces as they apply to automobile racing.
4. Encourage students to make their own observations, ask questions and offer other examples that illustrate these concepts in everyday life.
5. Follow up with discussions of Bernoulli's principle.
6. Ask students to draw their own illustrations of Bernoulli's principle or free-body diagrams on the board.

Assessment

Have the students complete Student Activity Sheet #4B: Ground Effect Innovations to assess their learning and understanding.

ground effects innovations in Automobile Racing

Question for Analysis

What are ground effects? How do they use physics principles? How are they important for racecars?

Key Concepts

Airfoil
A winglike device on a racecar that creates downforce as the air flows over 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 force on a car that pushes it downward, resulting in better traction.

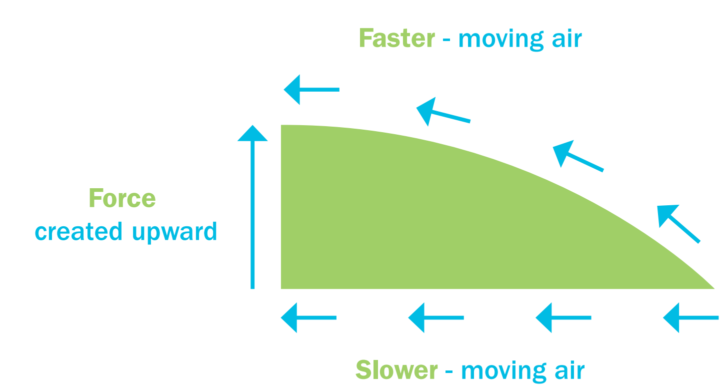
Ground effects
The effects from aerodynamic designs on the underside of a racecar, which create a vacuum.

Pressure
Force divided by area.

Motion of Air and Its Effects on Racing

Racecar 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 racecar, which creates a vacuum.

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. 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. In the drawing below, note that the air is coming in from the right.

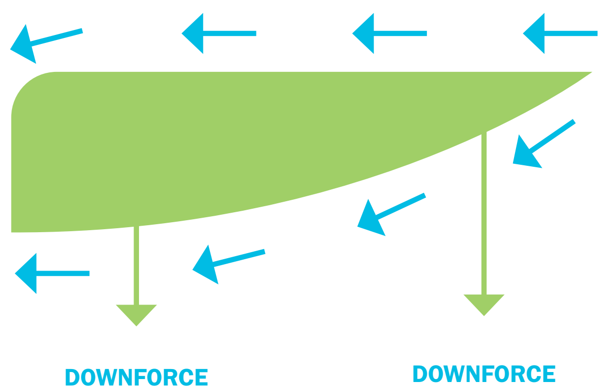


Continued...

Downforce and Bernoulli's Principle

Racecar engineers have used this concept to make small winglike objects called airfoils. They are actually wings turned upside down, so the longer surface is on the bottom. The wing is attached to either the front or the back of the car to push down on the car, thus gaining better traction. Look at the airfoil on the Texaco Star racecar [March 84C Race Car, 1984 (aerial view ID# THF69371)].

The airfoils are attached to the top of the car above either the hood or rear area. As the air passes over the airfoil, the faster-moving air below causes a drop in pressure under the wing and a comparatively higher pressure above the wing. A force is created from high pressure to lower pressure. This effect causes a downforce to force the car down.



The faster-moving air goes under the airfoil wing. The faster-moving air causes a drop in pressure. The drop in pressure causes a downward force.

There is a second way to gain downforce. The fronts of racecars (and 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 against the front of the car.

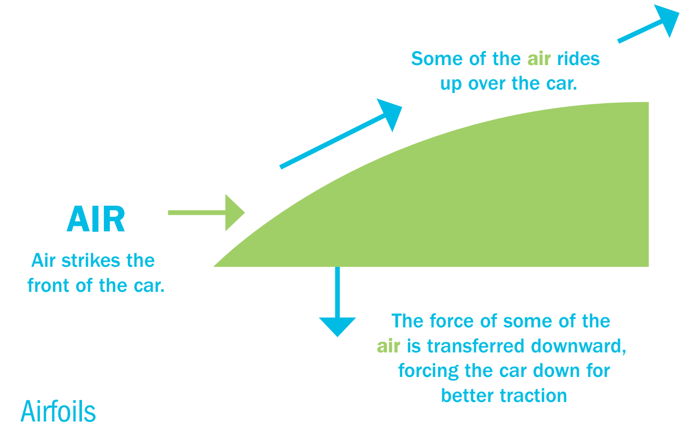
Wind Resistance

A large force in racing is wind resistance, or drag. At high rates of speed, the air pushes against the front of the car. This causes a great force against the racecar.

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). This car certainly would cause a great amount of air resistance, requiring the car to push the air. The force of the air would have slowed the acceleration and speed of the car. To decrease the air resistance from its large, flat front, the top of the Gasser was "chopped" off and lowered. 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.

Notice the difference between the shape of the Gasser and the shape of the Ford Thunderbird [Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (aerial view ID# THF69264)]. The front of the Thunderbird is slanted forward. This allows two advantages. First, the air rides over the top of the car without pushing straight back against the car so there is less force opposing the car's motion. Second, when the air hits the front of a racecar with a low front and continues over the top, the air actually pushes down on the front of the car to give it better traction. There is a downward force on the front of the racecar that gives the tires better grip and allows for faster cornering. Notice that the low-sloped front causes the oncoming air to push down on the front of the car.

Continued…



Airfoils

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 Texaco One Car [March 84C Race Car, 1984 (side view ID# THF69368)].

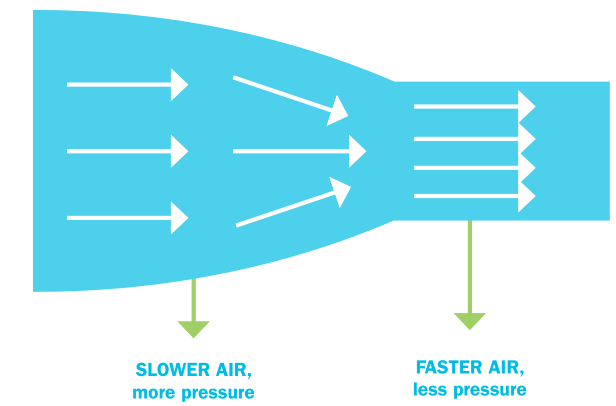
Notice how the air moves in from the left. The air strikes the front of the airfoil, which is slanted downward on this side. The angle of the air against the foil causes a push, or force downward. The airfoil is attached to the hood and therefore forces the car downward onto the track, allowing greater traction for cornering.

The drawback to using the airfoil angled downward is that it increases the force against the front of the car, slowing it down. This represents 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.

Venturi Effect

Another method of achieving downforce is through the Venturi effect. When air, a fluid, travels through a space that changes from a large cross-section to a smaller cross-section, the same amount of fluid (air) must pass through the constriction, so the air gains speed there. Faster-moving air causes a decrease in pressure, so there is a force, or pressure, created toward the faster moving air.

If the Venturi section is placed beneath the racecar, the car will be forced down for greater traction.



Jim Hall, Aerodynamics Innovator

Automobile racing has not always taken advantage of aerodynamics in the ways described here. Jim Hall, an engineer and former racecar driver from California, pioneered a new way of thinking about and using aerodynamics in the 1960s and 70s. Rather than trying to prevent aerodynamics from hurting the car's performance, Hall began searching for methods of using aerodynamic force to help the car. He especially worked on increasing the downforce on his cars, which would help them hold the road better, particularly on turns. He did this with wings and the shapes of car bodies. His cars won a number of races, both in the United States and in Europe, and profoundly influenced race car design. Hall's next innovation was to suck air from underneath the car instead of using air to press down on the car from above. He did that with a fan driven by a separate motor from the car's motor. It worked so well that his competitors got the innovation banned. Racing rules makers often outlaw new innovations, just to give other race teams a chance. Wings were also banned after competitors did a poor job of imitating Hall's wings, resulting in racing accidents. Even though his original solutions were banned, Hall inspired others to keep looking for a positive way to use aerodynamic forces, leading to the development of ground effects.

Name

ground effects Innovations

1. Why do racecars drivers race so closely together, often in a long row?

2. Using your own words and diagrams, describe how air creates downforce as air passes over an airfoil.

3. Compare the air flow around the Willys Gasser, 1958 (front view ID# THF69394) with the air flow around the Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (aerial view ID# THF69264).

4. Describe the forces from the air around the Indianapolis-style car March 84C Race Car, 1984 (aerial view ID# THF69371).

5. Why do you think that all NASCAR racecars in the same race must weigh 3,400 pounds, be no closer to the ground than 1 inch and be exactly the same height?

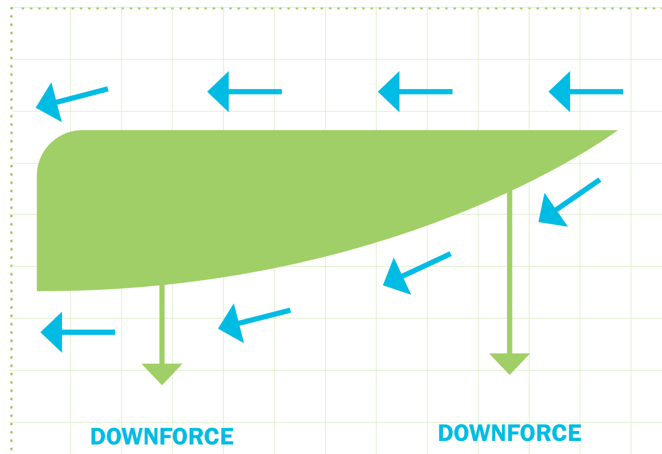
motion and Energy

1. Why do racecars drivers race so closely together, often in a long row?

The air rises over the first car and then continues over the second car without causing a force on the front of the second car. The air flows over each succeeding car in the same manner so that they need not fight the wind. The front car also benefits, because a vacuum forms behind the first car, actually giving it push.

2. Using your own words and diagrams, describe how air creates downforce as air passes over an airfoil.

The airfoils are attached to the top of the car above either the hood or rear area. As the air passes over the airfoil, the faster moving air below causes a drop in pressure under the wing and a comparatively higher pressure above the wing. A force goes from high pressure to lower pressure, causing a downforce on the car.



The faster-moving air goes under the airfoil wing. The faster-moving air causes a drop in pressure. The drop in pressure causes a downward force.

3. Compare the air flow around the Willys Gasser, 1958 (front view ID# THF69394) with the air flow around the Ford Thunderbird, NASCAR Winston Cup Race Carr, driven by Bill Elliott, 1987 (aerial view ID# THF69264).

The front end of the Willys Gasser is fairly flat, which means the "Gasser" has to push more against the air. The opposing force of the air decreases the possible speed of the "Gasser." The red Thunderbird is aerodynamically engineered with a sloping front to allow the air to pass over with less back force, so the red Thunderbird can travel faster and get better fuel mileage.

4. Describe the forces from the air around the Indianapolis-style car March 84C Race Car, 1984 (aerial view ID# THF69371).

- *Car is slender, so it has less air resistance.*
- *Car nose is knife-like, so it causes less air resistance.*
- *Airfoils can be adjusted for greater downforce to corner better.*
- *There are no extra grills or other objects to catch the wind.*

5. Why do you think that all NASCAR racecars in the same race must weigh 3,400 pounds, be no closer to the ground than 1 inch and be exactly the same height?

NASCAR does not want the cars to travel too fast because the chances for accidents increase with too much speed. Having the same weight controls accelerations. (More weight or mass means less acceleration.) The distance under the cars must be a distinct height so everyone experiences the same downforces. The height affects the air resistance. By controlling the heights, the speeds are controlled for safety.

Lesson 5 Work, Energy and Power in Automobile Racing

Question for analysis

How is energy transformed from one type to another in automobile racing?

Key concepts

- Acceleration
- Electrical energy
- Horsepower
- Kinetic energy
- Potential energy
- Thermal energy
- Power
- Aerodynamics
- Frame of reference
- Joule
- Momentum
- Relative motion
- Work
- Watt

Digitized Artifacts From the Collections of The Henry Ford

Lesson 5
Work, Energy and Power in Automobile Racing

- Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328
- Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)

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
- Background Information Sheet for Students #5A: Work, Energy and Power in Automobile Racing
- Student Activity Sheet #5B: Work, Energy and Power
- Answer Key #5B: Work, Energy and Power

Duration 1-2 class periods (45-60 minutes each)

Instructional Sequence

1 Discuss the general concepts of energy with the class. Ask students to list the different forms of energy. Ask the students to explain any formulas they know that involve the types of energy.

2 Explain different forms of energy.

3 Distribute copies of Background Information Sheet for Students #5A: Work, Energy and Power in Automobile Racing. If possible, access this online so that students can view the digitized artifacts embedded and hyperlinked in the Background Information Sheet.

4 Use the Background Information Sheet to review, read and discuss with students the question for analysis and concepts and information about work, energy and power as they apply to automobile racing.

5 Encourage students to make their own observations, ask questions and offer other examples that illustrate these concepts in everyday life

6 Follow the reading with a class discussion on converting energies.

Assessment

Have the students complete Student Activity Sheet #5B: Work, Energy and Power to assess their learning and understanding.

work, energy and power in Automobile Racing

Question for Analysis

How is energy transformed from one type to another in automobile racing?

Key Concepts

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

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

Electrical energy
Energy derived from electricity.

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

Horsepower
A unit for measuring the power of engines and motors based on the average rate at which a horse can do a certain amount of work; 1 hp (horsepower) is equal to 746 watts of power.

Joule
The unit of measurement for energy; 1 joule = 1 kilogram * meter2/ second2.

Kinetic energy
Energy of motion; kinetic energy = ½ mass * velocity2, or KE = ½ m * v2.

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

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

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

Relative motion
The comparison of the movement of one object with the movement of another object. Thermal energy: Heat energy.

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

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; work = force * distance, or W = F d.

Work and Kinetic Energy

In order to move an object such as a racecar, something or someone must apply a force though a distance, so that work is accomplished. The energy from the work is thus transformed into to kinetic energy, or energy of motion.

Transforming Energy

Remember that energy cannot be created or destroyed. Energy can only be changed from one type into another. If a person does work by providing a force on a car, such as a push, then the energy of work comes from the calories in the food the person has eaten. The food energy is transformed into work energy and then into kinetic energy, or energy of motion as the person pushes the car, and the car gains kinetic energy as it moves. The kinetic energy of the car will then be transformed into heat energy, or thermal energy, in the friction of the brakes or the tires against the track.

Performing Work

One way of doing work to provide kinetic energy is by simply pushing an object such as a car. In both NASCAR and Indy-style races, when the cars are in the pit or the shop area, for safety reasons they need to be pushed by hand since these areas are crowded both with spectators and with people working on the cars.

How much work does it take to push a racecar through the shop area? Look at the digitized image of the pit crew pushing a racecar [Three Men Pushing a Barber-Warnock Special Race Car Off the Track at Indianapolis Motor Speedway, probably 1924 ID# THF68328]. If a force of 2,000 Newtons is provided for a distance of 20 meters, how much work is done?

Work = Force * distance; W = F * d = 2,000N * 20 m = 40,000 joules

This work will be transferred to the kinetic energy of motion, KE = ½ m * v^2. In theory, the kinetic energy will be a measure of the work done. Thus, 40,000 joules of work = 40,000 joules of kinetic energy.

If the kinetic energy is known, the velocity can be calculated. Assume the mass of the car is 3,400 pounds = 1,545 kilograms.

KE = 40,000 j = 40,000 kilogram-meters^2/second^2 =

½ m * v^2 = ½ * 1,545 kg * v^2

½ * 1,545 kg * v^2 = 40,000 kilogram-meters^2/second^2

v^2 = 40,000 kilogram-meters^2/second^2/ (½ * 1,545 kg)

v^2 = 51.8 m^2/sec^2

v = 7.2 meters/second

Even though in theory the work could provide as much kinetic energy as 40,000 joules, in reality much of the energy from pushing will be lost due to friction. The real numbers for kinetic energy and velocity will be a lot lower.

Converting Energies

Cars that are actually racing go through several energy changes and are subject to many different forces. Their energy begins as chemical energy in fuel. The engine converts the chemical energy into thermal energy. Look at the digitized image of the racecar engine of the Ford Thunderbird #9 racecar [Ford Thunderbird NASCAR Winston Cup Race Car Driven by Bill Elliott, 1987 (engine view ID# THF69265)]. The thermal energy is converted to mechanical energy to the crankshaft and then the mechanical energy is transferred to the wheels, which move the car, giving it kinetic energy.

Racecar engineering begins with the engine. The more efficiently energy can be converted from chemical to thermal to mechanical to kinetic, the faster the racecar can move.

Analyzing Work and Energy

As a car comes out of the pits, the driver accelerates rapidly over a short distance, with the car's engine providing the force. As the engine force pushes the car through the distance, the racecar gains kinetic energy.

If a car comes out of the pit area and increases its speed from 60 mph to 200 mph over a distance of 150 meters, how much work will be done by the engine and what will be car's gain in kinetic energy? The car has a weight (or mass) of 3,400 pounds, and 3,400 pounds * 1 kilogram/2.2 pounds = 1,545 kilograms. Note that in order to calculate kinetic energy, mass must be in kilograms and velocity must be in meters/second.

For the car exiting the pit at 60 mph, first calculate the its initial kinetic energy, then its final kinetic energy, and then its gain in kinetic energy. Note that 1 mile/hour = .447 meters/second, or m/sec.

Conversions

$$60 \text{ mi/hr} * \frac{.447 \text{ m/sec}}{1 \text{ mi/hr}} = 26.8 \text{ m/sec}$$

$$200 \text{ mi/hr} * \frac{.447 \text{ m/sec}}{1 \text{ mi/hr}} = 89.4 \text{ m/sec}$$

KE (initial) = ½ m * v^2 = ½ * 1545 kg * (26.8 m/sec)^2 = 5.55 x 105 joules

KE (final) = ½ m * v^2 = ½ * 1545 kg * (89.4 m/sec)^2 = 6.17 x 10^6 joules

KE (gained) = KE (f) - KE (i) = 6.17 x 10^6 j – 5.55 x 10^5 = 5.62 x 10^6 joules

To calculate the force of the engine

work = F * d = KE (gained)

F * 150 m = 5.62 x 106 j

Force = 5.62 * 10^6 joules /150 meters = 37,400 Newtons

Theoretical Situations vs. Real Situations

In a real situation, there is a great amount of friction, so the actual numbers would be substantially different from the results of theoretical calculations. However for a general understanding, we can ignore the friction and still gain an understanding of the concepts and necessary calculations.

Horsepower and Watts

Work is defined as a force applied through a distance, or

W = f d

Power is defined as work per time or energy per time, or

P = W / t

Another way to think of power is how rapidly work is completed. Power is measured in watts. One watt = 1 joule/second.

In automobiles in general, and in automobile racing, the amount of work an engine can exert is measured in horsepower (hp). The concept of horsepower was developed by James Watt (1736-1819). Watt was looking for a way to measure power, so he devised a method of having a horse lift a weight (of 33,000 lbs.) through a height (1 ft) in a period of time (1 min). He called the rate of 33,00 foot-pounds/minute 1 horsepower. One horsepower is equivalent to 746 watts, or 746 joules /second.

All of these terms and concepts can be used to explain the work and energy involved in automobile racing.

Equations

1 horsepower = 746 watts

P = W * t

W = F * d

Work = Energy / time

Work = Δ KE

KE = ½ m * v^2

Conversions

1 mile = 1610 meters

1 mile/hour = 1 mph = .447 meters/second

1 hour = 3,600 seconds

Name

work, energy and power

1. Follow all the energy conversions for a dragster, beginning with the car at the starting line, through accelerating, to braking after the finish line?

2. The engine of the Ford Thunderbird #9 is capable of producing 725 horsepower.

   a. How many watts would this be?

   b. How much work could the engine do in 1 minute?

3. How much work would be done by a NASCAR racecar if the engine produced 1,800 Newtons of force for a 2.5 mile lap at the Daytona International Speedway?

4. If a racecar is traveling at 200 miles/hour, how long (in seconds) would it take the car to make a 2.5 mile lap at the Daytona 500?

5. A force of 1,000 Newtons is applied for a distance of 50 meters.

   a. How much work is done?

   b. If the work continues for 20 seconds, how many watts are produced?

motion and Energy

1. Follow all the energy conversions for a dragster, beginning with the car at the starting line, through accelerating, to braking after the finish line?

   Begin with the potential energy of chemical energy in the fuel. The chemical energy is converted to thermal energy. The thermal energy is converted to mechanical energy to drive the car. The mechanical energy is converted to kinetic energy and then the kinetic energy is converted to thermal energy in braking.

2. The engine of the Ford Thunderbird #9 is capable of producing 725 horsepower.

   a. How many watts would this be?

      *725 hp * 746 watt/hp = 540,850 watts*

   b. How much work could the engine do in 1 minute?

      *540,850 j/sec * 60 sec = 32,451,000 joules*

3. How much work would be done by a NASCAR racecar if the engine produced 1,800 Newtons of force for a 2.5 mile lap at the Daytona International Speedway?

   *W = F * d = 1800 N * 2.5 mi * 1610 m/mi = 7,245,000 joules*

4. If a racecar is traveling at 200 miles/hour, how long (in seconds) would it take the car to make a 2.5 mile lap at the Daytona 500?

   *T = d / v = 2.5 miles / 200 mi/hour = .0125 hour .0125 hr * 3600 sec/hr = 45 seconds*

5. A force of 1,000 Newtons is applied for a distance of 50 meters.

   a. How much work is done?

      *W = F * d = 1,000N * 50 m = 50,000 joules*

   b. If the work continues for 20 seconds, how many watts are produced?

      P = W / t = 50,000 j /20 sec. = 2,500 watts

supplemental resources | for grades 9-12

Culminating Projects

Consider introducing these projects at the outset of the unit Physics, Technology and Engineering in Automobile Racing so students can gather information along the way. These projects are designed as opportunities for students to demonstrate their learning and their response to the question "What physics concepts can be learned by analyzing automobile racing?"

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

Online Individual Project

ExhibitBuilder: Curate Your Own Exhibition

Create your own exhibitions through **The Henry Ford's** website, TheHenryFord.org/education. Using what you've learned in this unit, the digitized images and the website, design an exhibition to illustrate physics and engineering concepts. Begin with the concept of innovation, in automobile racing as well as in passenger cars. You might extend the project to include innovations in other science and technology areas, such as flight or electricity.

Offline Individual Project

Innovation in Automobile Racing

Write a paper on innovations in automobile racing. Follow the history of the automobile and automobile racing from the early 1900s to modern times. The paper should include engineering concepts and the development of various safety features. Consider focusing on one of the following types of automobile racing: NASCAR (stock car), Indy style, Formula One or drag racing.

Offline Team Project

Group Work Rapid Problem Solving

Work in groups of 4-6 people. Choose an object to disassemble and reassemble in a short amount of time. As you learned in this unit, during racing every second counts, so think about the importance of teamwork and organization. Keep the object to a reasonable size that can be brought into the classroom. Bring the object into the classroom and demonstrate your team's skills for the class. This project should be judged on how the team uses the skills of every member and how rapidly the team disassembles and reassembles the object.

Extension Activities

These extension activities provide opportunities for the eager learner curious about topics related to automobiles and automobile racing.

Communication Skills in Automobile Racing

One of the more challenging aspects of racing, especially in NASCAR and Indy style races, is communication between the spotter and driver. At NASCAR races, each team has several spotters strategically placed around the race track to guide the racecar driver. Because of all the safety features and devices in a modern racecar, the driver has a difficult time seeing what is happening beside and behind him or her. Spotters need to help the drivers. The spotters must tell the drivers which way to move on the track to avoid hitting other racecars.

Have the students work in pairs. Set up an obstacle course in the classroom or hallway out of the way of desks or other objects. The driver will close his or her eyes or wear a blindfold. The spotter will walk near the "driver" and verbally guide the driver around the obstacles to the end of the course. Have the students switch roles so each student can understand the challenge of guiding someone with limited vision, the importance of excellent communication skills and the need for mutual trust when giving or listening to directions.

Design an Aerodynamic Car

Have students design and build an aerodynamic car. Students can design and build their cars out of modeling clay or play dough or they can even carve their car out of lightweight wood. Or they can mold the clay over a block of wood (as most car designers do). The cars should be about 10 inches long and less than 4 inches tall. Have the students tape small streamers (made from string) or small cloth strips to the back of the car. Set a fan in front of the car to simulate a wind tunnel and check the aerodynamics of the cars.

Evaluation of Family Car

Ask the students to look carefully at their own family car, van or truck. Ask the students to list 3 or 4 concepts that they would like to redesign to make the car either safer or more aerodynamic.

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Name

physics, technology and engineering in automobile racing
review/assessment questions

1. Draw a free-body diagram for a block being pushed across the floor.

2. Use all 3 of Newton's laws of motion to explain a racecar accelerating out of the pit area and increasing to race speed.

3. How much distance could a racecar and driver cover at 200 mph while her opponents are in the pits for 15 seconds?

4. How much force would it take to increase the speed of a 1,400 kilogram racecar from 0 to 180 miles per hour (80.5 meters/second) in 8 seconds? (Use meters/second for velocity when calculating force.)

5. Calculate the time it takes to complete a 500-mile race at Daytona International Speedway if a racecar covers 350 miles at 180 miles per hour and 150 miles at 200 miles per hour.

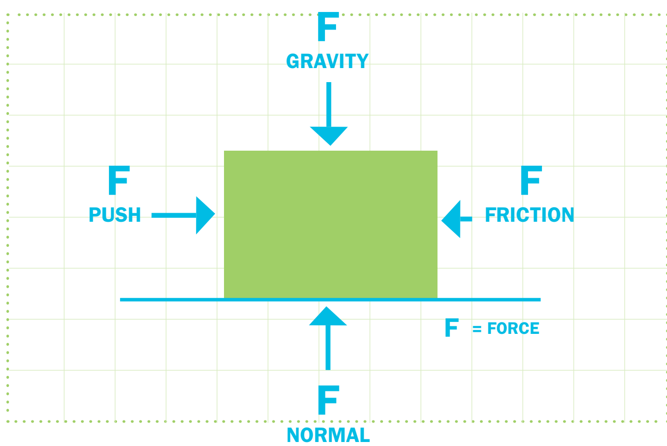
6. Explain at least 5 examples of Newton's laws of motion as they apply to an accident during an automobile race.

7. How much work and power does a racecar exert if the car creates a force of 400 Newtons through 100 meters over 4 seconds?

8. Explain which single innovation in racecar engineering you feel has been the most important.

physics, technology and engineering in automobile racing
review/assessment questions

1. Draw a free-body diagram for a block being pushed across the floor.



2. Use all 3 of Newton's laws of motion to explain a racecar accelerating out of the pit area and increasing to race speed.

Possibilities include

1st law

A. Car begins at rest but an outside force causes it to accelerate.

B. Once a racecar is moving, it keeps moving.

C. Driver feels the seat push on his back and neck during acceleration as she tends to remain where she was.

2nd law

A. The force of the engine causes acceleration.

B. The lighter the car the faster it accelerates.

C. Forces from friction on tires and wind force try to slow the racecar.

3rd law

A. The tires push backward and the track pushes forward.

B. If there is gravel or dirt on the track, the gravel or dirt will fly back as a car accelerates forward.

C. The car's seat pushes on the driver and the driver pushes back on the seat.

3. How much distance could a racecar and driver cover at 200 mph while her opponents are in the pits for 15 seconds?

First convert seconds of time to hours

*15 sec * 1 hr/3,600 sec = .00417hr*

*D = v * t = 200 mi/ hr * .00417hr = .83 mi*

The other cars would cover .83 miles while he is in the pits.

4. How much force would it take to increase the speed of a 1,400 kilogram racecar from 0 to 180 miles per hour (80.5 meters/second) in 8 seconds? (Use meters/second for velocity when calculating force.)

Acceleration a =

$\Delta v / \Delta t$ = 80.5 m/sec / 8 sec = 10.06 m/sec^2

F = ma =

*1,400 kilogram * 10.06 m/sec^2 = 14087 Newtons*

5. Calculate the time it takes to complete a 500-mile race at Daytona International Speedway if a racecar covers 350 miles at 180 miles per hour and 150 miles at 200 miles per hour.

Calculate the time for each section

T = d/v = 350 mi/ 180 mi/hr = 1.944 hours
T = d/v = 150 mi / 200 mi/hr = .75 hour
Total time = 1.944 hr + .75 hr = 2.69 hours

6. Explain at least 5 examples of Newton's laws of motion as they apply to an accident during an automobile race.

Examples include

A. 1st law: Once in motion, the car and driver tend to keep going.

B. 1st law: All the cars tend to keep going forward.

C. 2nd law: The brakes on a car will decelerate the car.

D. 2nd law: If a car hits another car, it will push and accelerate the car in another direction.

E. 1st law: 5-point seat belt keeps the driver from flying forward.

F. 1st law: If the tires hit the infield track while the car is sideways, the top of the car keeps going, and car flips.

7. How much work and power does a racecar exert if the car creates a force of 400 Newtons through 100 meters over 4 seconds?

***Work** = F * d = 400N * 100 m = 40,000 j*

***Power** = Work / time =*
40,000 j / 4 sec = 10,000 joules

8. Explain which single innovation in racecar engineering you feel has been the most important.

There are numerous possibilities, including safety devices, such as the HANS device, seat belts and roll bars; and engineering improvements, including aerodynamics and stronger engines.

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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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