Lesson 3
Forces Involved in Automobile Racing

Main Idea

Forces can be illustrated with examples from automobile racing.

Duration 1 class period (45 minutes)

Key Concepts

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

Racing Oral History Interviews:

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

Digitized Artifacts

from the Collections of **The Henry Ford**

Lesson 3 Forces Involved in Automobile Racing

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

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Lesson 3 Forces Involved in Automobile Racing Continued

Materials

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

Instructional Sequence

1 Introduction

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

2 Using the Racing Oral History Interviews

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

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

3 Finding Forces in Automobile Racing

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

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

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

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

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

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

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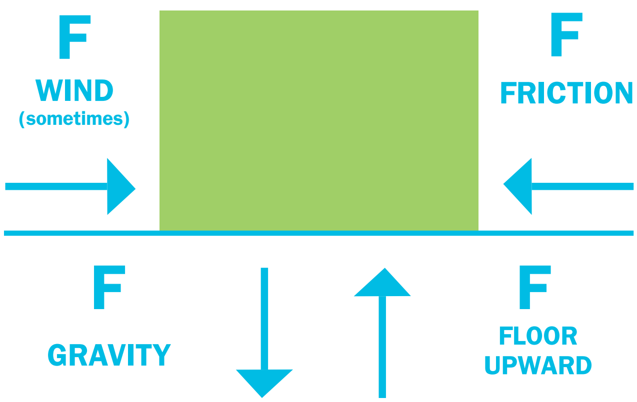
4 Representing Forces

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



5 Background Information for Teachers

Formulas Involving Force:

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

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

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

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

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

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

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

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

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

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

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

Assessment

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

forces involved in Automobile Racing

Key Concepts

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

More about Force

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

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

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

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

Forces on Larger Cars

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

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Centripetal Force

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

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

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

Tire Forces

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

Other Problems

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

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

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

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

Continued…

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

Center of Gravity

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

Drag Force, or Wind Resistance Force

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

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

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

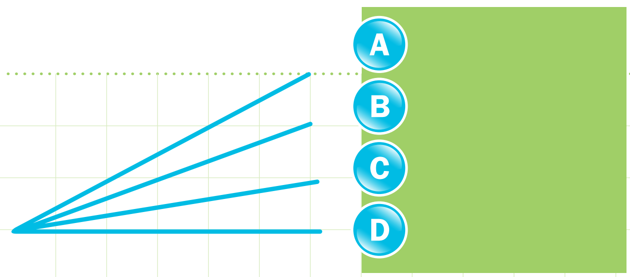
When the Gasser's owner, George Montgomery, finally retired the Willys, he replaced it with a modified Mustang that was much lower and had better aerodynamics.

forces

Name ______________________________

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

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



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

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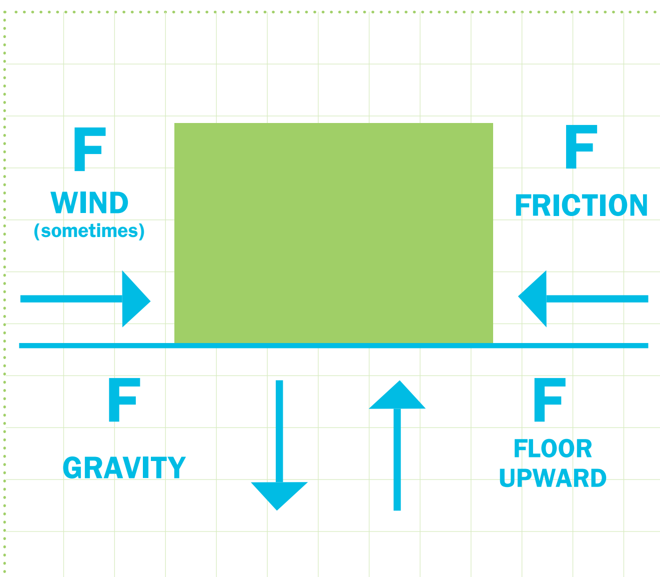

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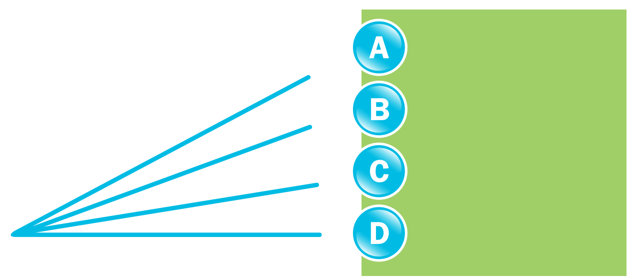

Angle A allows the greatest racing speed, and Angle D allows the least racing speed.

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

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

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