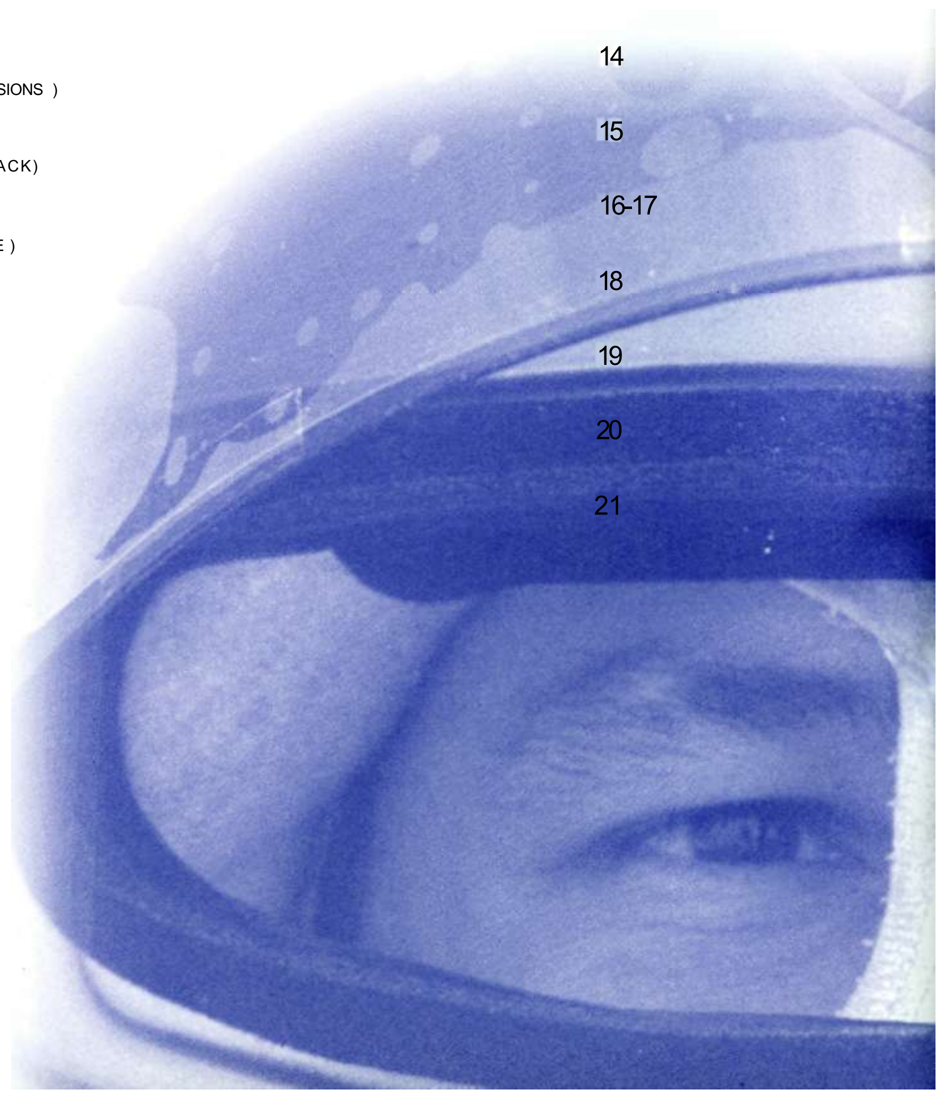
SUPER SPEEDWAY

A GIANT SCREEN EXPERIENCE

TEACHER'S GUIDE

Contents



Introduction

This teacher's guide is intended for use with *Super Speedway,* a giant-screen motion picture that follows the design, fabrication, testing and racing of an Indy car. The purpose of this guide is to help educators build on the learning opportunities the film presents for students.

The students start their *Super Speedway* experience with a pre-screening activity entitled *Fast Machines,* which challenges them to design a basic race car.

After seeing the film, the students will return to the activities in this guide to explore different aspects of race cars and the scientific principles that explain how they perform. They will also be given opportunities to apply what they have learned and to improve on the cars they designed in the first activity.

The activities are designed for students between grades 4 and 12. Each activity has a section entitled "Taking It Further," which allows the students to explore the topics in more depth.

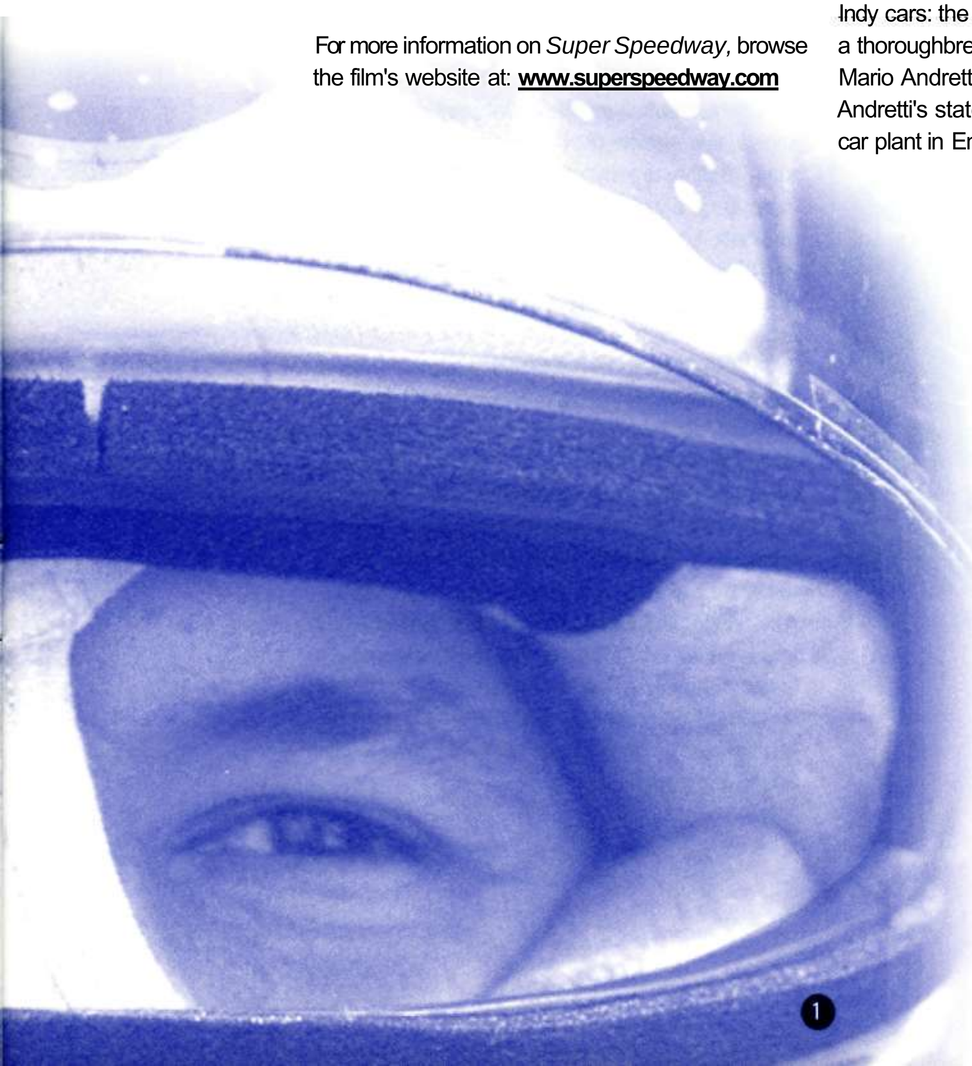
For more information on *Super Speedway,* browse the film's website at: **www.superspeedway.com**

Film Summary

Buckle up. *Super Speedway* delves into the death-defying drama of Indy car racing and weaves together the stories of some of the masters of the high-speed track. The film puts audiences in the cockpit of an Indy car and catapults them into world championship auto racing action at mind-bending speeds in excess of 230 miles per hour.

At the core of the film's action is Michael Andretti and Newman/Haas Racing, the team he drives for. Together, driver and team test a newly fabricated car and ultimately drive it in hot pursuit of the championship in the *PPG CART World Series.* Michael's efforts are seen through the eyes of his father, racing legend Mario Andretti, who participates in testing the new car and reflects on his own racing experiences and on the art, science and risk of high-speed competition.

Set against the drama of the track are two story lines that follow the remarkable craft of creating Indy cars: the restoration of a 1964 roadster-a thoroughbred once driven at Indianapolis by Mario Andretti - and the building of Michael Andretti's state-of-the-art Indy car at the Lola car plant in England.

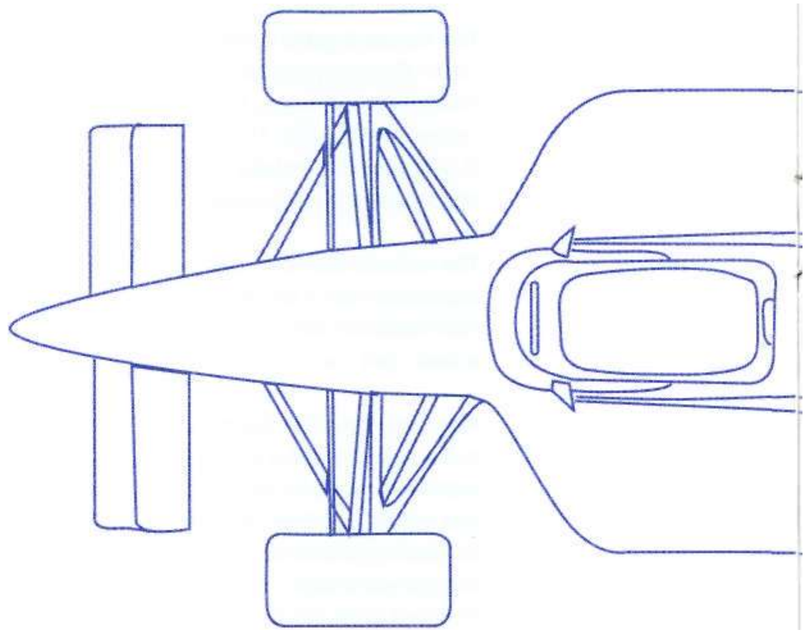


Fast Machines

PRE-SCREENING ACTIVITY

(DESIGN A RACE CAR)

Fast Fact:
In 1911, Ray Harroun averaged just under 75 miles per hour to win the first Indianapolis 500. Today, Indy cars reach speeds of over 230mph, more than a Boeing 747 needs to achieve liftoff.



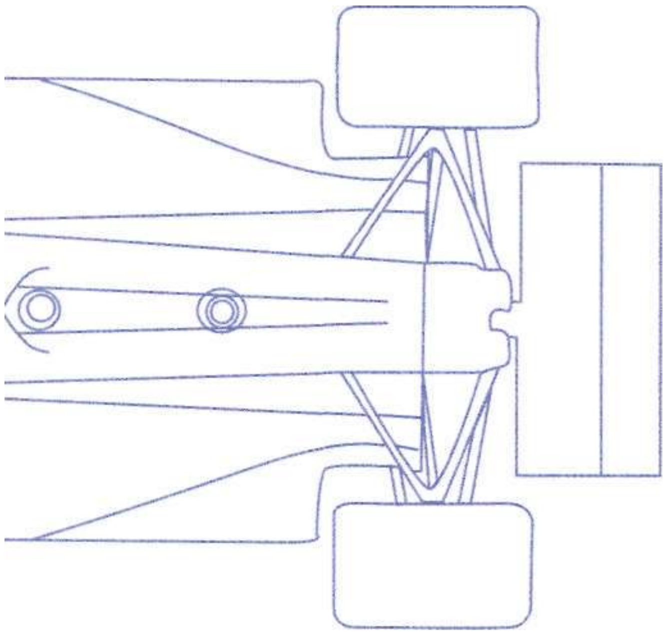
Objective:
The students will design their own race car.

In the Film:
In *Super Speedway,* engineers, mechanics, drivers and crew work year-round to build and maintain an Indy car that can compete and win races in the PPG CART World Series. There are many design factors to consider, among them safety, speed and reliability.

Background:
Race cars have evolved to high levels of sophistication since the first races at the beginning of the twentieth century. This evolution can be divided into two generations: the early cars, which culminated with the roadsters in the sixties, and modern Indy cars, which we see today. Racing organizations set rules for the sport in order to regulate and protect both the drivers and fans. Engineers build the fastest cars they can within the limits prescribed by Championship Auto Racing Teams (CART), the sanctioning organization for the PPG CART World Series. Today's Indy cars are extremely safe in comparison to earlier roadster designs.

Activity:
In groups of four, have the students brainstorm and come up with their own race car design, focusing on both safety and speed. Ask them to create a sketch or blueprint of their concept. After seeing the film and completing the activities in this guide, the students will reevaluate their ideas and redesign their original car.

Materials:
Pencil and paper.



To Do:
Tell the students that they are to design a car that is as fast and as safe as possible. Inform them that they are going to see the film *Super Speedway,* and do some activities that will teach them about designing safe and fast race cars. Afterward they will have the opportunity to return to their designs and improve on them.

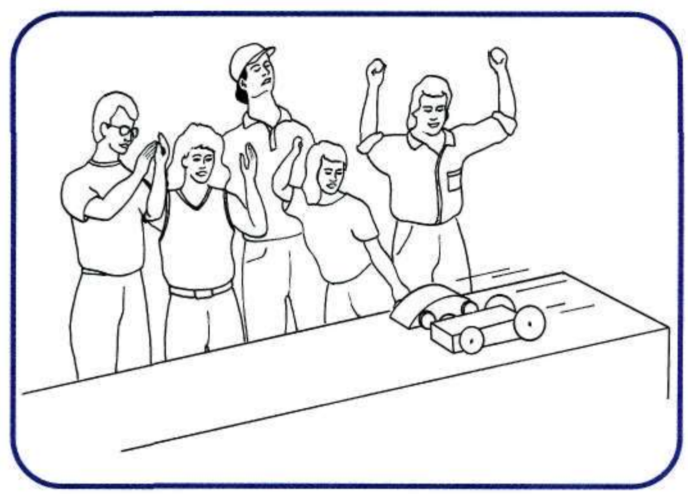
Have the students list as many parts of a race car as possible (i.e., tires, engine, cockpit). Ask them to sketch the chassis, or body, of the car. Have them decide where to position the driver's cockpit, the engine and the wheels to prevent the car from flipping over at high speeds. They have to choose which fuel to use to power the car and where the fuel tank will go. Should they use motor oil in the car? What features should the oil have? How fast do they think the car can go safely? How would they protect the driver?

Invite each group to share their design with the other groups. Create a list of the features a race car should have to make it as fast and as safe as possible. Be sure to collect the students' designs and their answers to the above questions.

After the students have viewed the film and worked on some of the activities in this teacher's guide, you should return to this pre-screening activity. Have the students change their designs in accordance with what they have learned. Ask them to explain their changes.

What's Going On?
The final designs should reflect a new understanding of energy, viscosity, safety, stability, aerodynamics, velocity and traction.

Taking It Further:
Organize a race event for the students. Encourage them to build a race car from materials they can find readily. They should try as much as possible to realize the designs they created in this activity.



Cardboard, tin cans or plastic bottles can be turned into rolling racers. In groups of four, have the students establish rules governing the design of their vehicles (i.e., what materials they can use, maximum and minimum dimensions and maximum weight).

A long ramp can serve as the racetrack down which the cars will accelerate. The cars can compete in time trials one at a time or in heats.

Powering the Beast

Activity 2

(TEST THE ENERGY OF FUELS)

Fast Fact:
Since the horrific crash and fire that killed drivers Dave McDonnell and Eddy Sachs in 1964, *methanol has* replaced gasoline as the fuel of choice at the speedway.

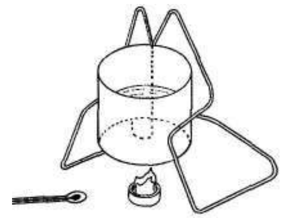
Objective:
The students will test the energy of different fuels.

In the Film:
Indy cars are fueled by an organic alcohol called methanol. More energy in each *fuel cell* means more speed on the track. How are different fuels tested?

Background:
When fuel is purchased it comes with energy already packed into the molecular bonds between the atoms. When this energy is released, heat is produced. Such reactions are *exothermic.* The amount of heat energy released may be estimated by measuring its effect on water temperature. Each gram of water requires 4.18 Joules (1 calorie) of energy to raise its temperature 1°C(1.8°F). Heat can be used to do work such as powering machines.

Materials:
A tin can, a coat hanger, water, a thermometer, a metal bottle cap, an eye dropper, safety goggles, a lighter, fuels such as gasoline, ethanol or methanol. (If these are not available, then methyl hydrate, kerosene, white gas or alcohol can be used.)

To Do:
Bend the coat hanger into a stand that will hold the can over the bottle cap. (If you cannot get it to form a stable stand, place the bottle cap between two bricks and put the tin can on them.) The students should be wearing goggles. Place a measured amount of room temperature water in the can. The amount should be the same for each trial: 50 to 100 cm^3 should be enough. Measure the starting temperature of the water with the thermometer. Use the eye dropper to



measure out a small amount of fuel into the bottle cap. The same volume of fuel should be used in each test. Taking care to observe all safety precautions, light the fuel. It will heat the water in the tin can. When all the fuel is spent, have the students measure the temperature of the water again. Ask them to calculate the temperature increase caused by the fuel. Repeat the experiment for each fuel. Which one warmed the water the most?

What's Going On?
The temperature change of the water is directly related to the amount of energy it got from the fuel. The fuel that raised the temperature the most is the fuel that produced the most energy per unit of volume.

Taking It Further:
1. Have the students study the by-products of each of the burning fuels. Which one produced the most smoke? What would this smoke do to the inside of an engine? How would it affect the spectators?

2. Ask the students to research the power of the fuel used in the main engines of NASA's space shuttle and compare it to methanol. Note that the by-product of NASA's fuel is just simple, pure water!

3. Give the students the task of researching horsepower. Have them explain why engine horsepower does not necessarily produce greater speed in a modern Indy car. The CART regulations require engines to be equipped with a "pop-off" valve which limits the power the engines can generate.

Activity 3

Lubrication

(TEMPERATURE VS. OIL VISCOSITY)

Fast Fact:
The crankshaft of an Indy car engine turns at astounding speeds - up to 14,500 revolutions per minute!

Objective:
The students will explore the effect of temperature change on the *viscosity* of different kinds of oil.

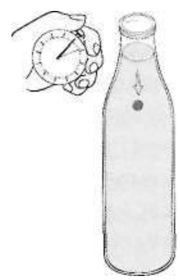
In the Film:
At the engine test center, engineers run the motor at high revolutions. You can see the exhaust manifolds turn red from the hot gases being expelled from the engine. Indy car engines must run at extremely high temperatures. Since heat affects the viscosity of liquids, it is crucial to choose the right oil for an Indy car. Oil is important because it is the only protection the motor has against the friction caused by the metal parts moving against each other.

Background:
Viscosity is the ability of a fluid to resist the forces that make it flow. High-viscosity fluids, such as molasses, do not flow readily; low-viscosity fluids, such as water, flow easily. When viscosity is optimum, the car's moving parts work with each other without direct contact by sliding against the oil. The oil flow is such that it does not impede the movement nor reduce the efficiency of the engine, but at the same time it does not allow the parts to come into direct contact with each other.

If the viscosity is too high, the oil flow does not allow the moving parts to move freely enough, therefore reducing engine efficiency. If the viscosity is too low, the oil flows too easily and the engine's parts rub against one another, causing friction and engine wear. This reduces the efficiency and life of the motor.

Materials:
Chick peas or other small seeds, four tall, clear glass jars (750 mL to 1L), 10W30 motor oil, 10W40 motor oil, vegetable oil, baby oil, oven mitts, a stopwatch.

To Do:
Fill each bottle with one of the oils to a height one centimeter below the mouth of the jar. Drop a chick pea into one of the oils and time how long it takes to reach the bottom. Repeat four times. Record the times. Repeat this procedure for each oil. Place the jars in a freezer for one hour, then do the same as before, recording the results. Place the jars in an oven at 125°C (250°F) for 30 minutes. Observing all safety protocols, remove the jars of hot oil from the oven using the oven mitts and repeat the same procedure, recording the results.



Have the students compare their results and discuss the viscosity of the different liquids at each temperature. Ask them to determine which oils would be better suited for a race car and which would be best for a car during the cold winter months.

What's Going On?
Baby oil has the lowest viscosity and 10W40 motor oil has the highest. All the oils lose viscosity when heated. When they become cold they all gain viscosity. Heat reduces the viscosity by decreasing the friction between the layers of molecules in the oils, allowing them to flow more easily. Cold does the opposite.

Taking It Further:
1. Ask the students to think about what parts of the car would be harmed by reducing the friction, for example, the brakes. Also, have them explore how heat affects other parts, such as the joints and tires.

2. Have the students consider using a lubricant on the race cars they designed in Activity 1.

Broken Heads

Activity 4

(CONSTRUCTING HELMETS)

Fast Fact:
Helmets are made of the same composite materials used to build a race car chassis: carbon fiber and kevlar. They weigh about 1.18 kilograms (2.6 pounds) today, which is half their weight 30 years ago. The helmet's visor, made of .125-inch-thick lexan, can resist the impact of a stone thrown at 483 km/h (300 mph.)

Objective:
The students will explore the construction of helmets that could one day save the lives of race car drivers.

In the Film:
Throughout the film you see drivers who are wearing full-face helmets. You also see engineers test an Indy car at the Cranfield Impact Centre. Testing helps engineers develop designs that reduce the risk of injury to the driver in case of an accident. A crash test dummy is used to simulate the driver. Improvements in car, track and equipment design have significantly reduced the number of fatal accidents, but racing remains a dangerous sport.

Background:
When an object slows, the energy that is lost must do something, so it exerts force. If the distance over which this force acts is small, the force will be considerable. By using padding in a helmet, the distance over which the force is dissipated is greater. Therefore, the force exerted against a driver's head in an accident is reduced.

Materials:
Different kinds of adhesive materials such as hot glue and tape, soft materials such as styrofoam, airfoam, plastics and bubble sheets, two dozen grade A large-size eggs, aprons.

To Do:
In pairs, the students place an egg lengthwise between the palms of their hands, with their fingers interlocked. Tell them to exert pressure against the ends of the egg. Make sure they are wearing aprons. Then have the pairs of students use different materials to make helmets for the eggs. Create a contest to see who can come up with the safest helmet design. To test their helmets, ask the students to drop the eggs from a height of 10m (11 yards) onto a hard surface. For a control, drop some unprotected eggs onto the same surface.

What's Going On?
When the students place pressure on the ends of the eggs, they shouldn't break. Eggs held lengthwise are structurally strong. When the unprotected eggs hit the hard surface, they will break. The eggs wearing helmets, which spread the force of the impact over a longer distance, may survive the fall.

Taking It Further:
1. Have the students examine the winning helmets and identify the protective characteristics of these designs. How do these characteristics work? Would they be good to incorporate into a race car driver's helmet?

2. The human brain is encased in its own natural helmet. Ask the students to compare the structure of the brain's helmet to the helmets they designed for their eggs. Also, have them compare the structure of the brain's helmet to the helmets designed for race car drivers.

3. Give the students time to redesign their cars to hold an egg during the race event. If the egg breaks, the car is disqualified. See how this affects their designs.

Activity 5

Wipe out

(GAIN STABILITY BY CONTROLLING THE CENTER OF GRAVITY)

Fast Fact:
During practice at Indianapolis, driver Rick Mears crashed and ended up upside down. When the car came to rest safely on its protective roll-bar, the only scrapes he had were on his helmet.

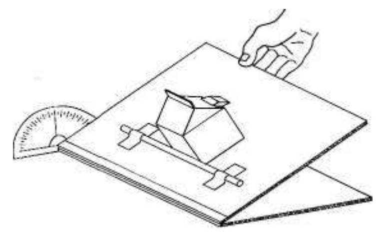
Objective:
The students will investigate stability and learn to control the location of the *center of gravity* of an object.

In the Film:
An Indy car driver is seated low in the car, in the middle and toward the front. The car itself is close to the ground and the wheels are far apart, keeping the center of gravity low. *Super Speedway was* filmed from an actual Indy car. During the filming, the engineers were concerned that the large motion picture camera mounted on top of the car would destabilize the vehicle, making filming at high speeds perilous.

Background:
For an object to remain stable, its center of gravity (the balance point of an object) must remain above its base. If the center of gravity is not above the base, the object will fall over. The base of a car is the rectangle formed by the four wheels touching the ground. In a high-speed turn, the sideways forces producing the turn tend to push the center of gravity out from above the car's base. This could flip the car over. How do engineers reduce the risk of an Indy car flipping over?

Materials:
Tape, 2 pieces of cardboard 15cm x 15cm (6 in x 6 in), a protractor, 1 straw 15cm (6 in) long, 150cm^3 empty milk carton, 6 metal washers.

To Do:
Following the illustration, create a ramp with two pieces of cardboard hinged together with tape. Make a ridge by taping a straw 2cm (0.8 in) above the hinge. Tape the protractor to the end of the cardboard to measure the angle at which it opens. Place the empty milk carton against the straw. Have the students slowly raise the cardboard until the milk carton falls over the straw. Record the angle.



Encourage the students to experiment. They can add between one and six washers at different areas on the milk carton to see if it will tip over at lower or higher angles. Have the students determine where the washers must be placed to make the milk carton the most stable. Ask them to explain in terms of the center of gravity and base area. How do their results compare to the design of Indy cars? How would they modify a car for a race on a flat oval track with only left turns?

What's Going On?
When the students first raise the milk carton and it falls, they discover its center of gravity. By adding weights and moving them around, they shift the center of gravity. When the washers are high up, the milk carton tips over at a smaller angle. This is because the center of gravity is also high up and therefore has shifted past the base area at a lower angle than the carton without washers. When the washers are on the bottom of the carton away from the straw, the milk carton is the most stable. The lower the center of gravity, the more stable the milk carton. Indy cars have their wheels far apart to keep their center of gravity very low. This helps prevent the cars from flipping over.

Taking It Further:
1. Ask the students to go back to the car they designed in Activity 1 and look at it in terms of its center of gravity.

2. Consider adding a sharp curve with a guard rail toward the bottom of the ramp developed for the race event in Activity 1. Use this as a testing ground for car stability. How are the various car designs affected?

Wings

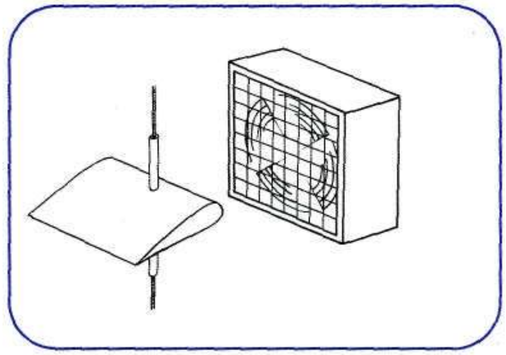
(USE WINGS TO MANAGE AIR FLOW AND IMPROVE PERFORMANCE)

Fast Fact:
Indy cars produce so much *downforce* at race speeds that they would be capable of driving upside down on an inverted track!

Objective:
The students will investigate how the shape of a race car's wings affect the flow of air over the car.

In the Film:
At the Cranfield wind tunnel testing center, a car is studied for aerodynamic performance. It is tested with a smoke stream and with ultraviolet dye, which provides engineers with a map of the car's aerodynamic flow. We see the engineers attempt, through trial and error, to find the best design to increase the speed of the car.

Figure 1.



Background:
Racer Jim Hall is considered to be the father of racing *aerodynamics.* His novel approach used air forces to improve performance. His experiments eventually led to the use of small wings to create downforce. Downforce is similar to lift on planes, only in the opposite direction. It is used to force a car's wheels to stay in contact with the track.

Materials:
A large electric fan with a variable speed control, paper, a straw, string, tape or a stapler.

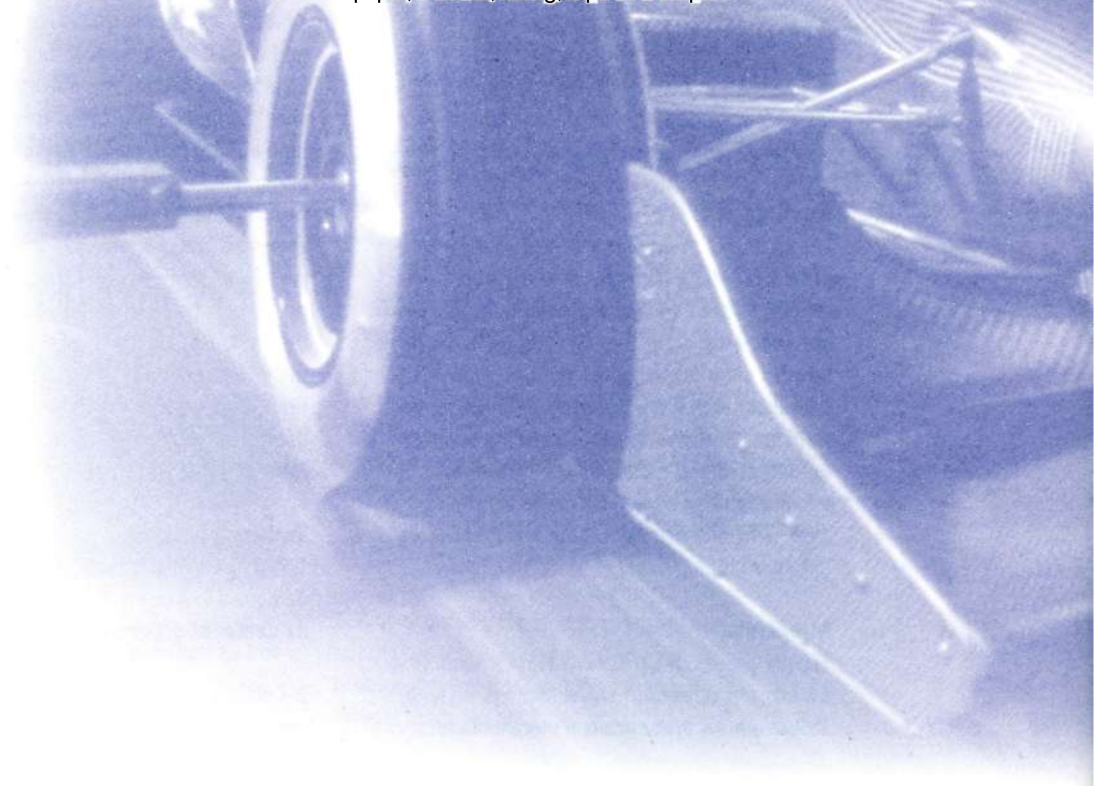
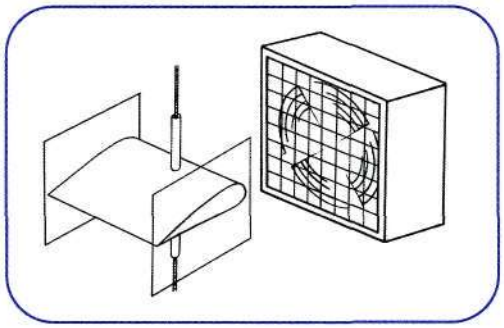


Figure 2.



To Do:

Have the students bend a sheet of paper in half widthwise and staple the top and bottom together without making a crease. Following the illustration (figure 1j, have them make a hole through both layers near the rounded end. Pass a straw through the holes. Pass a string through the straw, and hold the string taut and vertical. Tell them to place the paper in front of the fan and watch what happens. Encourage them to experiment by tilting the string forward, backward and sideways. Have the students consider why the "wing" moves as it does. Suggest that they draw how the air passes over the wing. How should a wing be shaped and which way should it be tilted on a race car?

What's Going On?

When the paper wing is hung from the straw it sags enough to round the top surface more than the bottom. When air goes over the rounded part of the paper (the wing), it creates a low-pressure area because the air has to travel further over the top than it does over the bottom. The relatively high-pressure area below the wing generates lift. When the string is tilted backward, the angle at which the air strikes the wing creates even higher pressure under the wing, generating more lift. Compared with an airplane wing, the wing on an Indy car is upside down. The net effect is lift in reverse, which is called downforce.

Taking It Further:

1. Ask the students to place cardboard side pieces across the ends of the wing as shown in the illustration (figure 2). How does this effect the stability and lifting power of the wing? How can this be used to increase the stability of a race car?

2. Have the students place wheels on the side pieces and put the wing on a board in front of the fan. The board represents the ground. Does the wind pick up the wing or push it toward the ground? Have them turn the wing over and try again!

3. Suggest that the students do research on aerodynamics. What are they and why are they important? How do the wings on cars differ in effect from the wings on airplanes? Give the students time to revise their designs from Activity 1 in terms of aerodynamic features. Hold another race event.

Downforce

Activity 7

(**REDUCE AIR PRESSURE UNDER THE CAR TO GAIN CONTROL**)

Fast Fact:
The side tunnels of Indy cars generate so much suction that manhole covers found on temporary street circuits must be welded down so they are not sucked off when the cars pass over them.

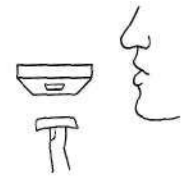
Objective:
The students will experience the reduction of air pressure, which helps press the race car to the pavement.

In the Film:
The shape of an Indy car is carefully crafted to create high and low air pressure areas. These areas produce downforces that enhance the performance of the car and hold it firmly to the track. In the film you see researchers test Indy cars at the Cranfield wind tunnel testing center to ensure optimal aerodynamic design.

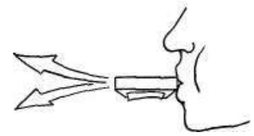
Background:
Race cars require a lot of pressure, or downforce, to hold them to the road's surface in fast turns. The Swiss scientist, Daniel Bernoulli (1700-1782), derived an equation that described the conservation of energy in a moving fluid. The equation explained the *Venturi Effect,* which is that less pressure is exerted in a more quickly moving fluid. In an Indy car, there are cavities under the body that channel air and make it move quickly. Air is a fluid. When it moves faster, its pressure lowers and a partial vacuum is created, pulling the car to the track.

Materials:
Scissors or a scalpel or paper knife, several small boxes open at both ends (such as the cover of a small matchbox).

To Do:



Have the students cut a small rectangular hole in the bottom side of one of the boxes. Tell them to hold a piece of paper under the hole and blow through the box. Suggest that they try holes of different sizes. Have them blow harder and softer. Help the students realize that the box is similar to a car, and the paper is similar to a road. Have them hypothesize about why the air pressure under the car would be much less than the pressure above the car.



What's Going On?
As the air flows through the box, it has more energy in the forward direction. It exerts less pressure sideways than does the more slowly moving air underneath the paper. The lower air pressure at the hole under the box allows the greater air pressure below the paper to push the paper up to the bottom of the box.

The box is similar to the car in that the shapes of the channels under the car make air funnel quickly through the cavities that are found there. This is like the fast-moving air blown through the box. The fast-moving air creates low-pressure areas under the car, just as the air pressure is lower at the hole under the box.

Taking It Further:
1. The next time they ride in a car, the students should roll down their window just a little and leave their hand inside the car near the opening. Holding a piece of paper close to the opening would illustrate the effect more clearly, but warn them to hold it tightly lest it fly right out the window. Have them describe what they experience.

2. Ask the students to float a small ball in a sink. They should run the tap water close to the ball. Have them experiment by directing the stream of water toward different parts of the ball. When is the ball drawn into the stream, and when is it pushed away? See if the students can explain the effect by identifying the regions of lower and higher pressure.

Activity 8

Traction

(**SURFACES AND FRICTION**)

Fast Fact:
Warming up for the start of a race, drivers zigzag, raising the temperature of their tires to improve traction. When cornering on the track, racing tires can reach temperatures of up to 188°C (370°F).

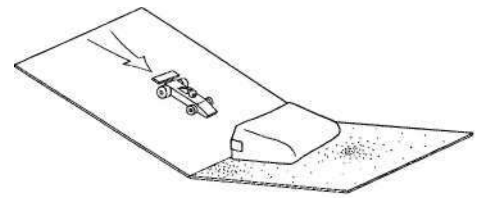
Objective:
The students will investigate the effects of friction and how different surfaces can affect the amount of friction.

In the Film:
The race car's sole connection to the track is through the contact patches, or "footprints," of its four tires. Different weather conditions require different tires and driving strategies. In the film you see weather conditions vary from race to race. Starting, slowing, passing and turning are all affected by weather and track conditions.

Background:
Friction is a slowing force caused by interactions between surfaces rubbing together. These interactions may be the result of *cohesion* or of molecular vibrations. If the interactions can be controlled, the friction can be controlled.

Materials:
Any toy car or truck, a ramp, paper, sandpaper, various kinds of tapes, plastic wrap, and sand or flour.

To Do:
Have the students fold a piece of paper and tape it to make a pocket. This pocket will capture the toy car as it leaves the ramp (see illustration). Ask the students to roll the car down the ramp into the pocket and measure how far along the flat surface the pocket slides until it stops. They may do this a number of times to get an average sliding distance.



Now have the students put tape on the underside of the paper pocket so that the pocket will slide on the tape instead of the paper. Repeat the experiment and note how far it slides. Repeat the experiment with a variety of different textures placed on the flat surface such as sandpaper and plastic wrap, with and without the tape. Finally, have the students sprinkle a tiny amount of flour over the flat surface to see how this affects the results.

What's Going On?
The friction force slows the pocket in each trial. The larger the force, the shorter the distance the pocket will travel. For example, the plastic wrap sticks to the table more readily than the paper because the molecules of the plastic are more cohesive. The pocket will stop in a shorter distance when sliding over the plastic wrap than over the paper. The flour reduces the molecular interaction, allowing the car to slide further.

Taking It Further:
1. Have the students try rolling the car from different ramp heights. If it is twice as high, does it slide twice as far?

2. Tell the students to place weights inside the pocket. How does this affect the distance of the slide?

3. See if the students can explain why different tires are used on a race car when it rains.

4. Have the students consider when it might be advantageous to have a lot of friction. What parts of a race car should have lots of friction?

5. Have them consider when a lot of friction is a disadvantage. What parts of a race car should have very little friction? Ask the students how this knowledge might be used to improve the car they designed in Activity 1.

Faster

Activity 9

(**MEASURE POSITIVE (AND NEGATIVE) ACCELERATIONS**)

Fast Fact:
At speeds in excess of 370 km/h (230 mph), a one-second delay in the pits will cost a driver the equivalent of the length of a football field.

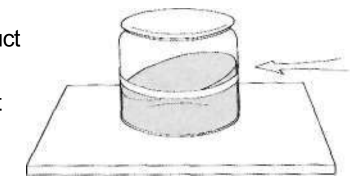
Objective:
The students will investigate the directions of positive and negative accelerations.

In the Film:
You see Michael Andretti and Mario Andretti bringing their Indy cars quickly around tight turns. *Acceleration* presses the drivers into their seats. The cars' wheels bite into the tarmac as they leap toward the straightaway. Each car must reach its top speed before the next turn.

Background:
Acceleration is the measure of how quickly a car can change its speed. A car's acceleration is directly related to the forces that act on the car. The friction of the tires on the pavement, the movement of air around the car, and the action of the powerful motor are all reflected in the car's acceleration.

Materials:
A jar with a lid, tape and water.

To Do:
Have the students half fill the jar with water, screw on the lid, and make a line around the water level as a reference. Next, they are to place the jar on a flat surface in a car, bus, wagon or other moving vehicle. Instruct them to note the movement of the water's surface when the vehicle accelerates, slows down, turns, stops, and moves at a constant speed (fast and slow). Ask them to record the direction the surface moves in for each event. This direction represents the direction of acceleration. Have them notice in particular when the surface in the jar is flat. See if they can explain the movement of the surface when the vehicle turns. Does it indicate acceleration? If so, which direction is it in? What does this suggest is happening to the fluids inside the driver as he or she accelerates?



What's Going On?
The water in the moving vehicle does not accelerate until there is a force acting on it. The water moves up the jar's wall on the side opposite the direction of acceleration. When the vehicle decelerates, the water again moves up the wall of the jar, on the side opposite the direction of acceleration. (NOTE: Deceleration is negative acceleration.) Similarly, during a turn, the water will move up the wall of the jar on the side opposite the direction of acceleration. (NOTE: The direction of acceleration in a turn made at a constant speed is exactly toward the center of the turn.)

Taking It Further:
Have the students calibrate the device used in this experiment. One way is to tape a scale to the jar, which will allow the relative sizes of acceleration to be compared. Ask the students to explore relative accelerations, for example, car versus bus and person versus bike.

Activity 10

Vroom

(THE DOPPLER EFFECT)

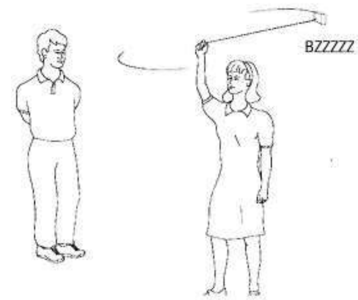
Fast Fact:
Police radar guns use the *Doppler* effect to determine whether cars are breaking the speed limit. The bigger the Doppler effect with the radar waves, the faster the car is going.

Objective:
Doppler shifting sounds will be demonstrated.

In the Film:
The "vroom" of cars going by is a familiar sound at the racetrack. The students will hear this sound during *Super Speedway.* As the cars flash by, the sound of the motors appears to change from a high pitch to a lower pitch, even though the cars are travelling at a constant speed.

Background:
When objects such as motors vibrate the air around us, we detect these airwaves as sounds. The pitch of the sounds we hear depends on the frequency with which the airwaves hit our ears. If the object is moving it can change the frequency of the waves. This effect was first analyzed by the Austrian physicist, J.C. Doppler (1803-1853).

Materials:
A cord, a buzzer or other noisemaker, a small bag or sock. Alternatively, a whistle attached to a plastic or rubber hose may be used.



To Do:
Choose one student to demonstrate. Place the buzzer in the sock and securely close the end of the socks with the cord. Leave several feet of cord free. Have the student swing the buzzer around on the end of the cord. Ask the other students to note when the pitch lowers. Is it when the object moves toward them, or away from them? A longer cord will make it easier for the students to hear the effect. (If some students have difficulty detecting the effect, instruct them to listen for a "wawa" sound.) Ask the demonstrator to increase the speed of rotation. What happens? Have the students describe how the changing sound of the buzzer is like the changing pitch of a car as it zooms by.

What's Going On?
When the source of the vibration (the buzzer) is stationary, the sound waves around the source are uniform. When the source moves, the centers of the waves shift. The waves in front of the moving object are packed closer together and we hear a higher pitch, whereas the waves behind the object are further apart. At the racetrack the speed of a race car is great enough to create this thrilling effect.

Taking It Further:
1. Have the students make sounds at different pitches by vibrating objects (rulers on the edge of their desks) at various speeds. Ask them to note how the musical pitch of the sound is related to the frequency of the object's vibration.

2. Have the students research how the colors of stars shift from red to blue in astronomy. Ask them to show how the color change is similar to the pitch of the Doppler effect.

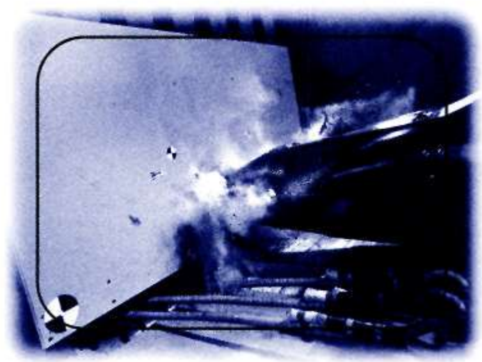
Impact!

(**ABSORBING ENERGY IN COLLISIONS**)

Fast Fact:
Modern Indy cars are designed to disintegrate in a collision, absorbing energy that would otherwise be transferred directly to the driver.

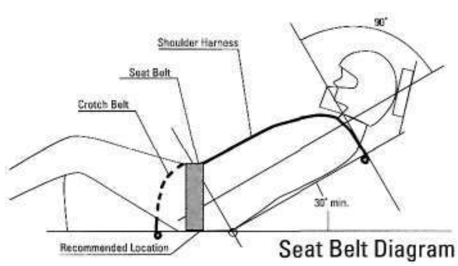
Objective:
The students will investigate different design strategies for keeping drivers safe in crash situations.

In the Film:
The possibility of a serious crash in car racing makes the sport a risky one. In the film you see a crash test. The purpose of the test is to evaluate the impact-absorbing qualities of an Indy car nose cone. You also see a roadster from 1964 being restored. During the roadster era, when a car crashed into a wall, its very rigid construction meant most of the force of the collision was transferred to the driver, resulting frequently in severe injury or death.

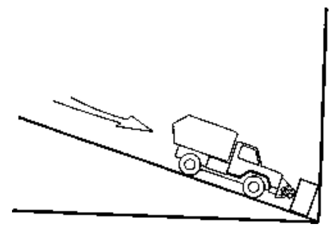


Background:
Safety standards are part of the PPG CART rule book. The carbon fiber chassis of a modern Indy car is designed to crumple on impact. In a head-on collision, for example, some of the energy that would have crushed the driver is used up destroying the nose cone instead. Energy-absorbing barriers are also used on some parts of the racetrack to improve safety.

Materials:
A Large toy car or truck, tape, candy-coated chocolates, bricks, a ramp, paper cups in the shape of a cone, a wooden board, empty pop cans, sand or fine gravel.



Seat Belt Diagram



To Do:
Tape a couple of candies to the point of impact of the toy car. Place the car at the top of the ramp and the brick at the bottom. Roll the car into the brick and have the students note the effect on the candies. Now tape a paper cup to the car and place some candies on the cup. Repeat the test crash. Ask the students to notice the effect it has on the candies. Now place a number of empty pop cans upright in front of the brick at the bottom of the ramp. Tape new candies to the bumper. Roll the car down the ramp into the cans and brick. What is the effect on the candies? Repeat using a pile of sand in front of the brick.

What's Going On?
In the first experiment much of the car's energy is used to smash the candies. In the second experiment the energy crumples the paper cup instead, and the candies are saved. In the third experiment some of the energy knocks the cans over instead of crushing the candies. In an Indy car, engineers make sure the forces are deflected to the car instead of the driver. The car crumples, but the driver is somewhat protected.

Taking It Further:
1. Have the students design their own bumper cover from paper and tape instead of a paper cone. Ask them to see if they can make it with less paper than is used in the cone.

2. Ask the students to explain why the front end of their parents' car is designed to collapse on impact. They should base their answers on the concept of energy.

3. Have the students incorporate safety features into the designs of their race cars for another race event.

Fire

(CONTROLLING FIRE AT THE TRACK)

Fast Fact:
Methanol, which is used to fuel Indy cars, burns with a clear flame, making it a potentially invisible hazard in daylight. However, methanol is less explosive than gasoline and is readily dispersed and extinguished with water.

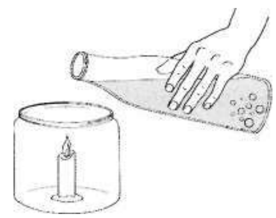
Objective:
To demonstrate how fires are put out at the racetrack.

In the Film:
With the large amounts of methanol fuel being handled in the pits and travelling on board fast-moving cars, fire is a major hazard at the track. Numerous regulations exist to prevent fires and to control them when they break out. Each car has an automatic fire extinguisher system, each pit contains at least one fire extinguisher, the crew wears fireproof suits during pit stops, and the drivers wear suits made of fireproof materials.

Background:
Combustion requires three things: fuel, oxygen and a high temperature. Without all three, a fire will stop. Carbon dioxide is used to put out fires of highly combustible materials such as those found at airports and racetracks. CO_2 pushes oxygen, which is lighter, away from the fuel, stopping the combustion. CO_2can be used to quickly extinguish the fire in a car, but can be dangerous around the driver as it would deprive him or her of oxygen. While rescue squads attend to the drivers, water is used to disperse the methanol and cool down materials that might ignite from the heat.

Materials:
Baking soda (sodium bicarbonate), vinegar (acetic acid), a small jar (between 250mL and 500mL), a large jar (between 750mL and 1L), plasticine or modelling clay, a small birthday candle, matches or a lighter.

To Do:
The students must follow all safety protocols. Working in pairs, have them attach the candle to the bottom of the small jar with the plasticine. Pour about 200mL of water into the large jar with 125mL of vinegar. Then add about 15mL of baking soda. Stand back and watch the chemical reaction. Have the students light the candle in the small jar. They should then slowly tip the large jar over the opening of the small jar without pouring out any of the liquid. What happens? Ask the students to observe the substance formed in the jar and name two physical properties (i.e., color) and one chemical property (i.e., the smell that came out of the jar). Their answers should be based on the results of the experiment.



What's Going On?
When baking soda is mixed with an acid such as vinegar, a chemical reaction occurs that produces CO_2 (carbon dioxide). Since CO_2 (a gas) is heavier than air, it pushes the air out the top of the jar in order to occupy the bottom. When you tip the bottle, the heavier CO_2 goes into the small jar, filling the bottom and replacing the oxygenated air. The CO_2 deprives the flame of oxygen, snuffing it out. Some of the properties of CO_2 are that it is a colorless, odorless, tasteless gas that has a greater density than air and does not sustain combustion.

Taking It Further:
1. Ask the students to research various fire extinguisher designs.

2. Have them explain the strategies behind each of the extinguishers they researched. They should base their answers on the three requirements of combustion.

On the Speedway

(THE GRAPH PAPER RACE GAME)

Objective:
The students will develop strategies and use vector component skills.

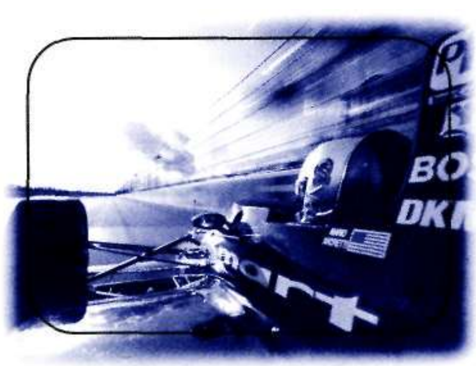
In the Film:
Racing strategy is dictated by a driver's experience and by the field of competition. When the race is on, you try to follow your game plan. However, you cannot predict the moves of your opponents, nor a host of other factors. You will need contingency plans, and you must be prepared to implement them.

Background:
Velocity can be thought of as having two independent components, namely, forward or backward and left or right. In this game the students must control movement in both directions: forward or backward, left or right.

Materials:
Graph paper and pencil.

To Set Up:
Following the illustration, draw the outline or "walls" of a raceway on a few pieces of graph paper. Mark a start line and a finish line for each raceway. Divide the class into groups of three or four. Give each group an outline of the raceway. The students may design their own racetracks in later games. Have them learn and follow the rules below.

The Start:
Choose the order of play (who goes first). Each car picks a position on the start line, beginning with the first player. Cars are always placed at the intersection of graph paper grid lines. Cars begin with a velocity of (0,0), that is, zero squares forward and zero squares to the side.



To Move:
Each car in turn may choose to change velocity in either of the directions or not. The velocity may change forward or backward by only one unit. The velocity may also change left or right by only one unit. The new velocity (forward or backward and left or right) must be recorded (see example in figure 1) and then plotted out on the graph paper (see example in figure 2). Note that a component must go to zero before it can change direction. If a car lands outside the raceway or if any point along the path of the car touches a wall, that car has crashed and is out of the race. A car may not land on a position already occupied by another car. The driver must change velocity to avoid a collision with another car, even if it means crashing into a wall.

Figure 1: Velocities recorded by players (sample game)

Move	Player ●	Player ■
Start	(0,0)	(0,0)
1	(1,0)	(1,0)
2	(2,0)	(2,0)
3	(3,1)	(3,1)
4	(4,1)	(4,1)
5	(5,2)	(5,1)
6	(4,1)	(4,1)
7	(3,0)	(3,0)
8	(3,-1)	(3,-1)
9	(4,-1)	(2,-1)
10	(3,0)	(2,0)
11	(2,0)	(1,1)
12	(1,2)	(0,2)
13	(0,3)	(0,3)
14	(-1,4)	(-1,4)
15	(-2,4)	(-2,3)
16	(-3,3)	(-3,2)
17	(-4,2)	(-4,1)
18	(-4,1)	(-5,1)
19		(-5,0)
20		(-4,0)
21		(-3,-1)
22		(-2,-2)
23		(-1,-3)
24		(0,-2)

A car crashes into the wall at move #19 and is out of the race.

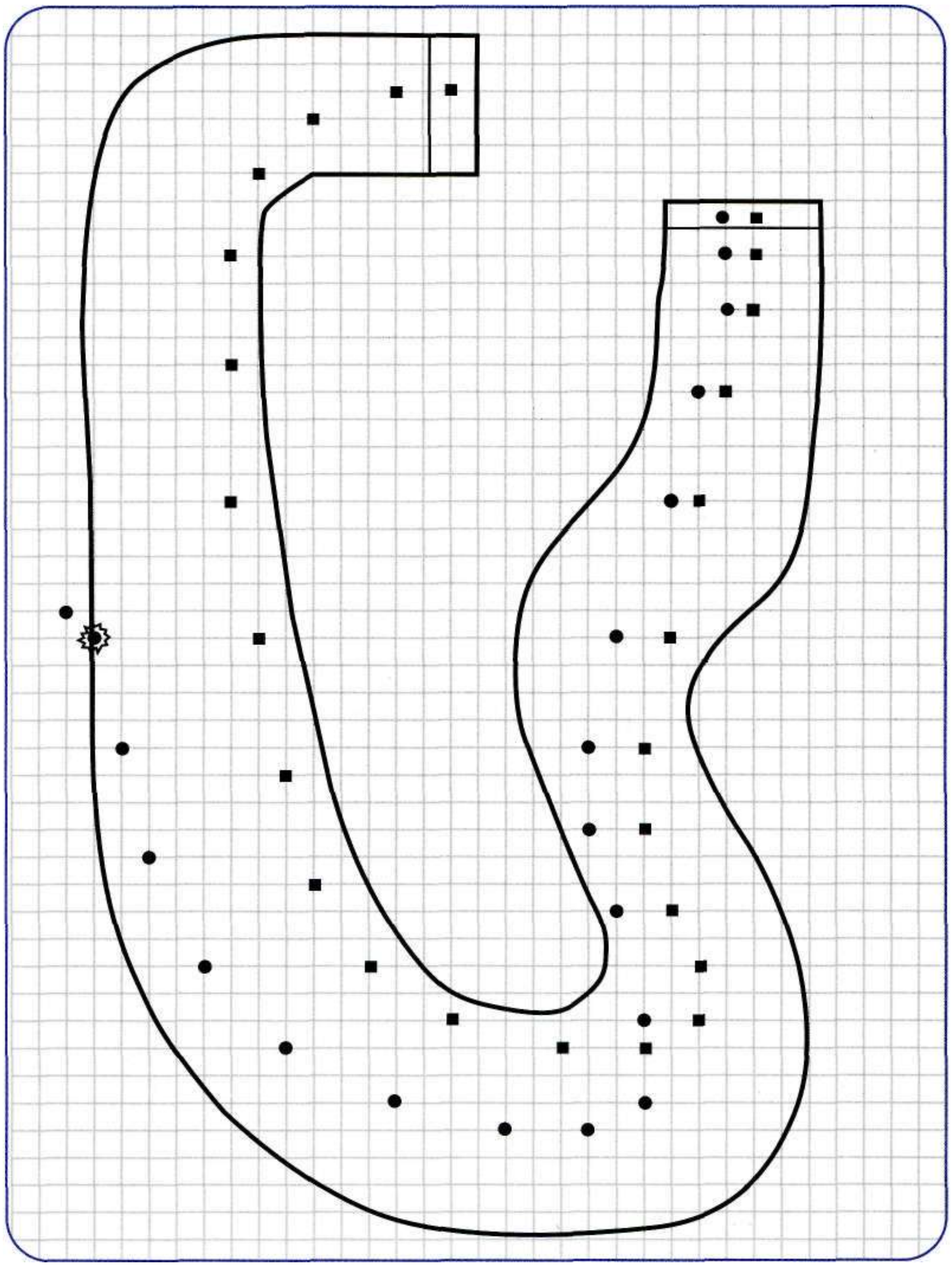
To Win:
The first car to reach the finish line, regardless of starting position, wins.

What's Going On?
The students have to keep track of their velocities in both directions and make decisions based on their speed and the changing shape of the track. What they record in brackets (see example in figure 1) is the car's velocity at a given point in time. What they plot on the track (graph paper) is the car's new position caused by that velocity. The maximum one-unit change in velocity is the allowable acceleration (or deceleration) of the car. The best way to play the game is very close to the way real drivers must learn to make turns. The game also illustrates the need to slow for turns.

Taking It Further:
1. Different turn shapes and narrows determine the degree of complexity of a raceway. The students can design different raceways to vary the game's difficulty.

2. The rules may be varied. For example, speeding up and/or slowing down can change by two or three units instead of just one.

Figure 2: Position on the track as plotted by players in sample game.



Around the Globe

Activity 14

(THE GEOGRAPHY OF RACING)

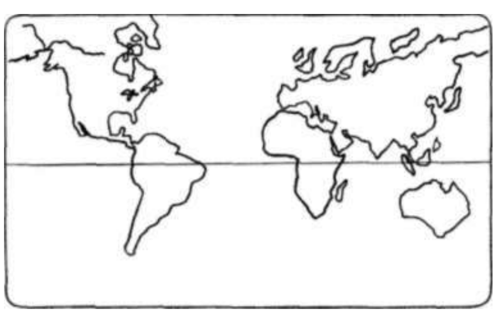
Fast Fact:
CART race teams employ up to 50 people, spend between $10 and $15 million U.S. per season, and travel to some 17 different race locations.

Objective:
The students will explore geography based on where CART teams drive. They will also practice measuring distances.

In the Film:
A PPG CART team travels all around the world to race. In the film you see several different locations of races. The students see that race team members include drivers, engineers, fabricators and crew. Team costs include salaries, travel, lodging, rental cars and meals during the season and throughout the off-season, when development and testing is conducted.

Materials:
A world atlas, a world map, a globe, a pencil, a ruler, paper.

To Do:
Using the map, have the students circle and label each city that an Indy team travels to. Ask them to use the sample racing schedule to measure and calculate, with the help of the map's scale, how far the race teams travel from race to race, starting in Homestead, Florida. Have them repeat the exercise on the globe. Instruct them to compare the appearance of the distance on the map to the appearance on the globe. (Use a string and the globe's scale to measure distances.)



Sample Racing Schedule

Mar. 02	Homestead, Florida
Apr. 06	Gold Coast, Queensland, Australia
Apr. 13	Long Beach, California
Apr. 27	Nazareth, Pennsylvania
May11	Rio de Janeiro, Brazil
May24	Madison, Illinois
Jun. 01	West Allis, Wisconsin
Jun. 08	Detroit, Michigan
Jun. 22	Portland, Oregon
Jul. 13	Cleveland, Ohio
Jul. 20	Toronto, Ontario
Jul. 27	Brooklyn, Michigan
Aug.10	Lexington, Ohio
Aug.17	Elkhart Lake, Wisconsin
Aug.31	Vancouver, British Columbia
Sep.07	Monterey, California
Sep.28	Fontana, California

What's Going On?
The true distances are those on the globe. Maps distort distances in order to flatten the surface of the globe for paper reproduction. The exact method of calculating distances on a map depends on the type of projection the map uses to represent the three-dimensional globe.

Taking It Further:
1. Have the students design their own schedule of races with one race in each city. They should try to find the schedule that makes the total distance travelled between cities as short as possible.

2. Have them design a schedule of races so that they leave their home city (number one on the race schedule) and visit each city only once. Then they must go back to their home city. Finding the shortest possible path is called "the travelling salesman problem."

3. Ask the students to imagine that they manage a racing team. Have them do research on the costs involved in operating it. How much does it cost to build an Indy car? How much should they spend on research and development? They should give a detailed breakdown of the expenses.

More Fast Facts

• An Indy car weighs only 1,550 pounds, 220 pounds less than the diminutive Suzuki Swift!

• An Indy car rolling chassis (the car without its engine, turbocharger, electronics or tires) costs $420,000 U.S.

• It costs a minimum of $8 million U.S. per year to run a car in the PPG CART World Series.

• Indy cars have a maximum length of 16 feet 3 inches (4.95 metres), a maximum width of 6 feet 6 inches (1.99 metres) and a maximum height of 2 feet 8 inches (.81 metres).

• Four major car manufacturers - Ford, Honda, Mercedes-Benz and Toyota - are fighting for supremacy in designing the fastest engines for the PPG CART World Series.

• Sweating can cause a driver to lose up to 10 pounds (4.5 kilos) during a two-hour race.

• Indy cars can generate four Gs (four times the Earth's gravity) of lateral acceleration driving around the fastest corners.

• Michael Andretti has won more CART races than any other active driver. He has captured more than 35 wins since he began in the series in 1983.

• Mario Andretti held the world closed-course speed record; he lapped the Michigan International Speedway at a speed of 234.275 miles per hour (377.042 km/h) on July 31,1993 (broken by Jimmy Vasser, age 31, in 1996).

• In 1990, Al Unser Jr. drove the fastest 500-mile race ever, averaging a speed of 189.727 miles per hour (305.347 km/h) at Michigan International Speedway.

• In 1995, Canadian Jacques Villeneuve became the youngest ever PPG CART Champion at the age of 24.

Glossary

Acceleration:
The measure of how quickly a velocity changes when an unbalanced force acts on an object. Acceleration is measured in meters per second per second (or feet per second per second).

Aerodynamics:
The study of air in motion.

Bernoulli Principle:
Based on conservation of energy in moving fluids. It states that a moving fluid, such as air, will exert less pressure when it is moving quickly than when it is moving more slowly. The principle is named after Swiss scientist, Daniel Bernoulli. (1700-1782).

Center of Gravity:
The center of gravity of an object refers to its balance point.

Cohesion:
Molecules of one type attract molecules of another type. (Adhesion is one type of molecule attracting a molecule of the same type.)

Downforce:
Downforce pushes the Indy car against the track. It is similar to lift on airplanes, only it is in reverse. Downforce is measured in newtons or pounds. It enhances traction in the corners allowing drivers to take corners at higher speeds.

Doppler Effect:
When objects such as motors vibrate the air around us, we hear these airwaves as sounds. The pitch of the sound we hear depends on the frequency with which the airwaves hit our ears. If the object is moving, it changes the frequency detected by our ears. This effect was first analyzed by the Austrian physicist, J.C. Doppler (1803-1853).

Exothermic:
Refers to any chemical reaction that releases more energy than it uses. (*Endothermic* refers to any chemical reaction that absorbs more energy than it releases).

Fuel Cell:
Individually fabricated to fit the design of each car, these bladderlike gas tanks are made to military ballistic specifications with heavy-duty I rubber material. They are located behind the driver and in front of the engine and are virtually puncture-proof.

Methanol:
Methyl alcohol is a colorless, poisonous liquid (CH_3OH) that can be used as a fuel or as a solvent. Methanol can be made from wood, or manufactured synthetically.

PPG CART World Series:
Driving open-wheel racing cars, drivers and their sponsoring teams compete in some 17 events in four countries (United States, Canada, Brazil and Australia). The series is organized and regulated by CART (Championship Auto Racing Teams). Races are held on four different types of tracks: Superspeedwavs, short ovals, temporary street circuits and permanent road courses. Events are broadcast on a live or tape-delay basis in 197 countries.

Venturi Effect:
Less pressure is exerted laterally in a fluid when it is moving quickly than when it is moving more slowly. This principle was explained by Swiss scientist, Daniel Bernoulli, in the eighteenth century.

Viscosity:
Viscosity is the ability of a fluid to resist forces that make it flow. Low-viscosity liquids such as water flow easily, whereas high-viscosity liquids such as molasses flow sluggishly. When the oil's viscosity is optimum in a car, moving parts slide on the oil, allowing them to move against each other without direct contact.

Credits

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WITH THE TEAMS AND DRIVERS OF THE PPG CART WORLD SERIES NARRATED BY PAUL NEWMAN
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