

The Science Behind Safe Driving: Educator Companion Guide



Introduction

Welcome to **The Science Behind Safe Driving**! This program is designed to help students learn fundamental principles of physics that can be applied to driving in an engaging, digital environment. With this digital interactive, students will be challenged to demonstrate how an understanding of the Laws of Motion can lead to an understanding of safer driving habits.

While seat time for students will vary, the interactive is designed to take 20-25 minutes for students to complete.

Educational Standards

Next Generation Science Standards

- **HS-PS2-1.** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- **HS-PS2-2.** Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

- **HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Materials

To help students navigate the interactive, you will need:

- A computer or other device with Internet access and a web browser
- A projection device to display the web pages (if using with a group)

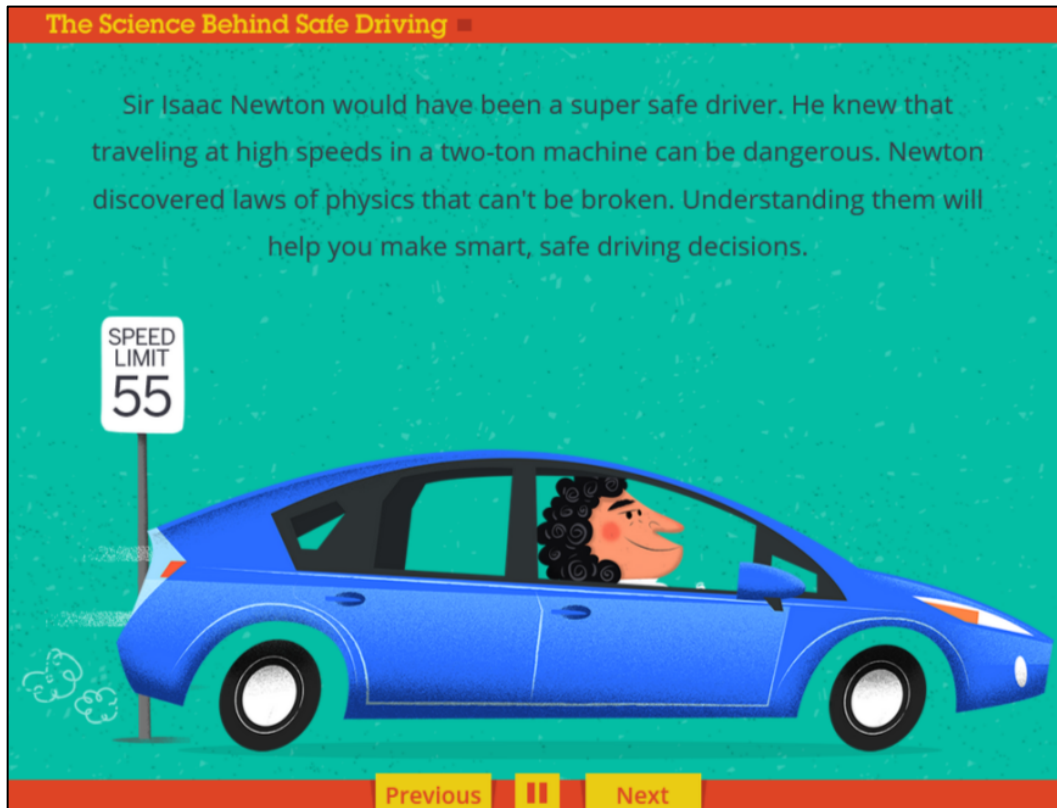
Procedure

This module is designed to be used by individual students in a self-paced setting or, if technology is limited, in a one-to-many environment. If using the module as a presentation in a one-to-many environment, the instructor can use the navigation features of the module to present the content to students and to set the pace of the lesson. By eliciting group responses, the instructor can facilitate interaction between students about their experiences and ideas and initiate small group discussions.

Throughout this guide, you will encounter Keys to Safe Driving. These Keys provide practical – and critical – information to students on how to apply the learning from this module in real-world driving situations. Be sure to discuss the Keys to Safe Driving with your students. You are encouraged to print the Keys to Safe Driving pages for distribution to students.

Section 1: Introduction

Estimated time to complete: 2 minutes



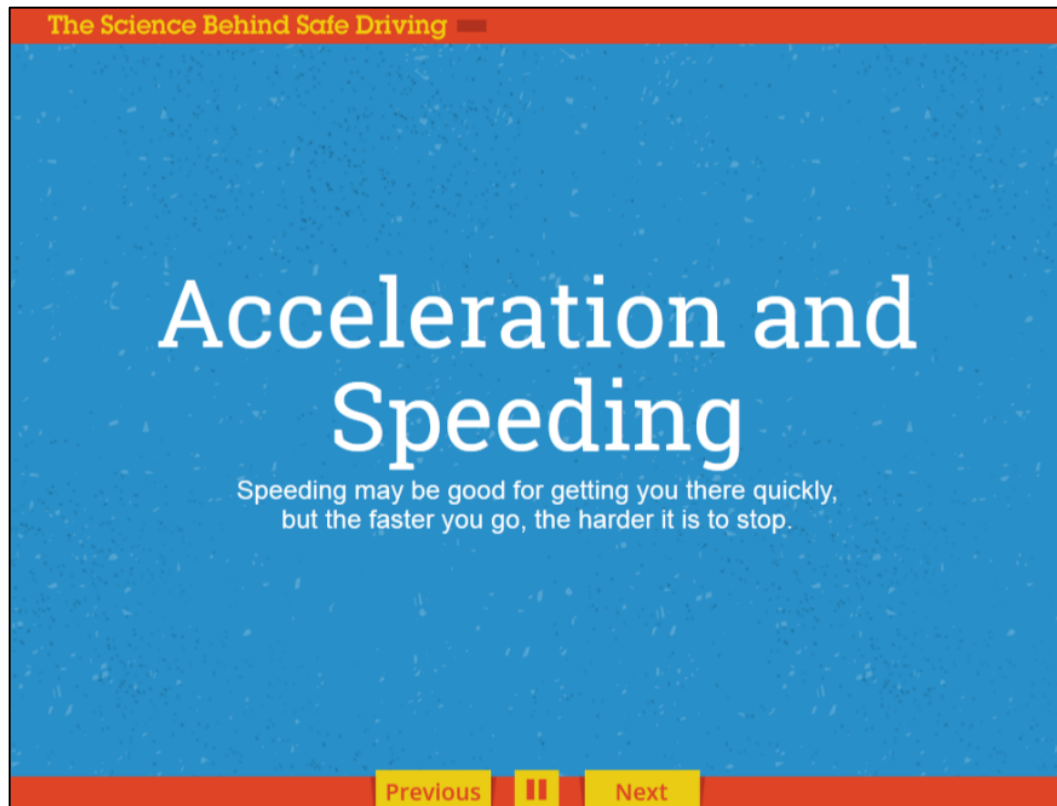
Section 1 – Screen 1

In the first screen of the setup, students are introduced to the main idea of the interactive: A solid grasp of Newton's Laws of Motion can help you be a safer driver.

Section 2: The Laws of Motion and Driving

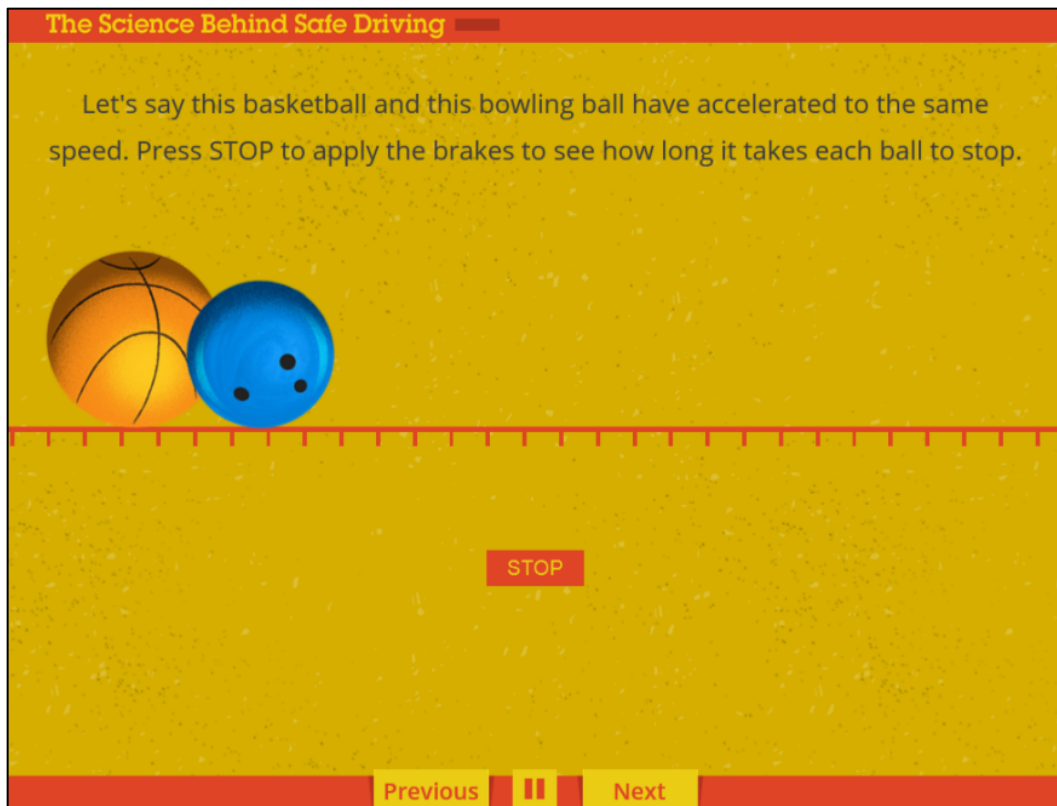
Driving Laws You Can't Break – Acceleration and Speeding

Estimated time to complete: 15-20 minutes



Section 2 – Screen 2

Section 2 delves into the Laws of Motion as they pertain to driving. Prior to beginning the activity, students who have had exposure to the concepts of speed and acceleration can be prompted to describe and differentiate them. Acceleration is the rate of change of velocity and is related to Newton's Second Law of Motion. Speed is distance traveled per unit of time. The topic of velocity may be reviewed, reminding students that velocity is a vector quantity.



Section 2 – Screen 3

On the next screen, students learn about how Newton's Second Law of Motion, sometimes called the Law of Acceleration. The law states that the acceleration of an object is directly proportional to the net force applied to it and inversely proportional to the mass. The Second Law of Motion is often expressed as $F=ma$, where F is the net force, m is the mass of the object and a is the acceleration.

Since both objects have the same speed, their deceleration to a final speed of zero will be dependent directly on the brakes (the force), which is the same for both objects, and their masses, which differ. The bowling ball, being more massive, will take longer to stop. This is shown on the next screen.



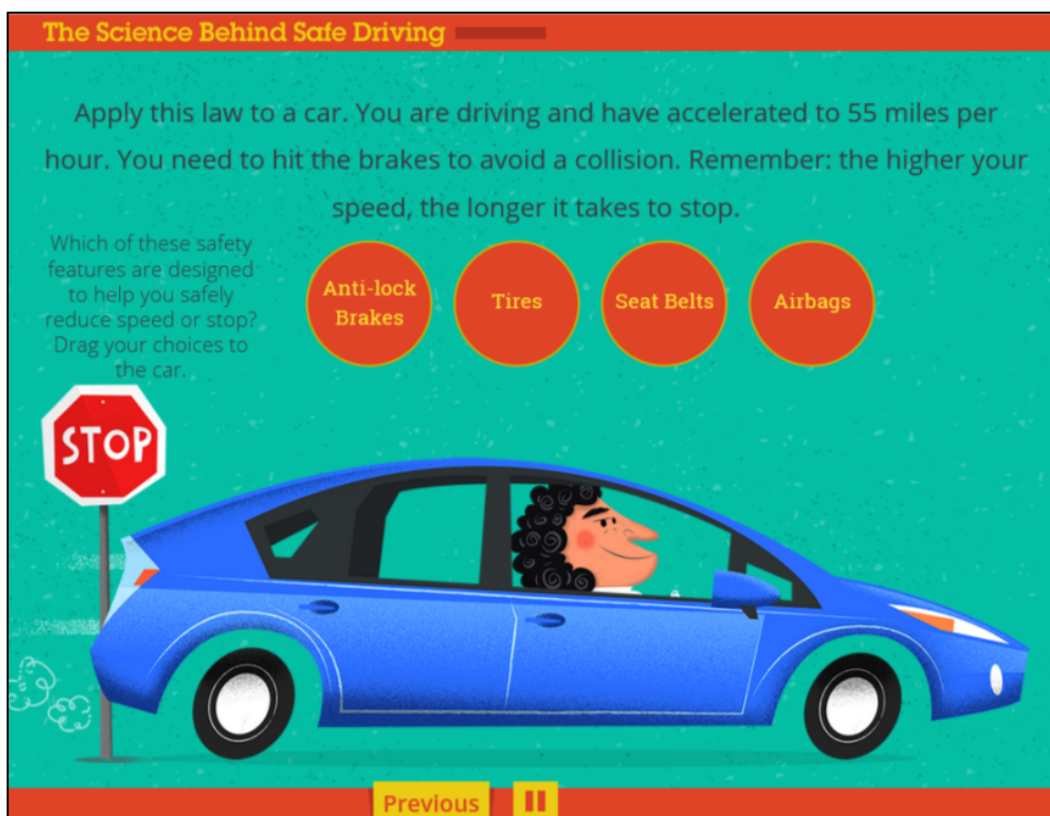
Section 2 – Screen 4

This screen shows that, although both objects have the same speed and the same force applied to stop them (the brakes), it takes the more massive bowling ball longer to stop.



Section 2 – Screen 5

Unbreakable Law No. 1: The faster and heavier an object, the harder it is to stop. This statement is derived from Newton's Second Law of Motion, but it is one of the most relevant laws as pertains to driving. As speed and/or mass of a vehicle increases (e.g. a large delivery truck vs. a car or an unloaded car vs. a car pulling a trailer), the distance needed to safely stop increases. Awareness of this relationship is essential to driver safety!

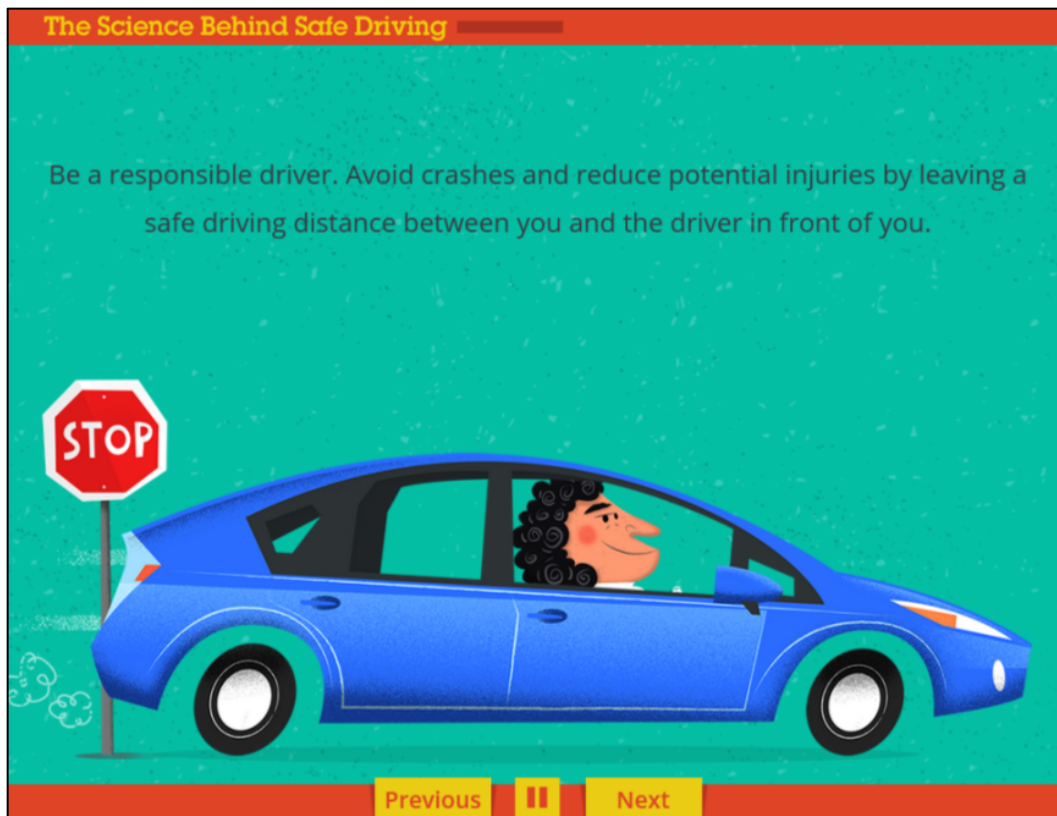


Section 2 – Screen 6

Now students explore how different safety features affect the stopping distance. Note that students are reminded that all of the safety features on the screen are important, but they should select the appropriate safety features based on the scenario described on this screen.

- **Anti-Lock Brakes:** Anti-Lock Brakes help prevent loss of control. With the tires rolling, the driver still will be able to maintain directional control. However, if the brakes lock the wheel rotation, either due to over-application of the brake (emergency braking) or because the tires are on a low friction surface (wet or icy pavement), the ability of the driver to maintain control of the vehicle is diminished.
- **Tires:** Tires aid in reducing stopping distance – as long as they have good tread depth and are properly inflated. Friction is what keeps cars on the road and is the stopping force. The friction your car's tires have with the road is in part due to size and shape of the "contact patch," the portion of the tire that is actually in contact with the road. In the standard model of friction, friction is independent of both the surface area of the object and the velocity. However, there are many exceptions and this is a good example of one of them. Proper tire inflation is important. If tire pressure is too low, the tire bows and reduces the contact patch. If tire pressure is too high, the tire bulges and reduces the contact patch. Follow the manufacturer's recommendation for tire load and tire pressure to insure that your car has the optimum contact patch.
- **Seat Belts:** Seat belts are an important safety device but will not change the stopping distance.

- **Air Bags:** Air bags are an important safety feature but will have no effect on slowing or stopping.



Section 2 – Screen 7

When students get to this screen, they have successfully determined which safety features can help them slow or stop their vehicle.

Keys to Safe Driving: *Determining Safe Following Distance*

Being able to determine a safe interval between you and the vehicle ahead of you is dependent on the same principles being covered in this unit. This interval between vehicles is essential to give drivers both the time to react and the space and time in which to safely slow or stop their vehicle. The recommended following distance between vehicles (under ideal driving conditions) is 3 seconds.

To determine how far this distance is as you are driving, do the following:

1. Pick a marker on the road ahead, such as a road sign or telephone pole.
2. When the rear of the vehicle ahead passes the marker, count "one thousand and one, one thousand and two, one thousand and three."
3. When the front of your vehicle reaches the marker, stop counting. If you reach the marker before you count "one thousand and three," you are following too closely.

Remember that the 3-second rule gives a *minimum* following distance and applies *only* to ideal driving conditions. You will need extra space in certain situations, such as bad weather, when following motorcycles or large trucks, or when carrying a heavy load.

Section 2: The Laws of Motion and Driving

Driving Laws You Can't Break – Momentum



Section 2 – Screen 8

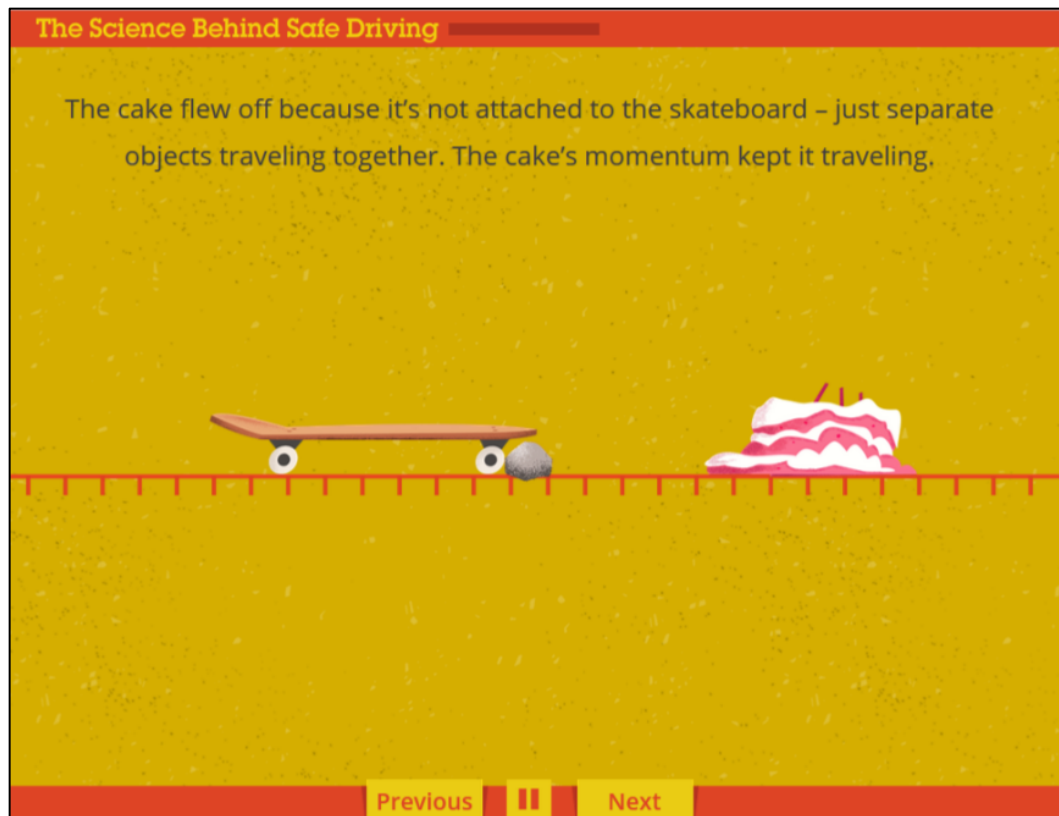
Momentum is a product of mass and velocity ($p=mv$) and has both magnitude and direction. Not only does momentum keep us moving, it keeps us moving in the same direction. This part of the simulation is based on the conservation of momentum; there will be no change in the momentum of an object unless acted upon by an outside force, a principle found in Newton's First Law of Motion.

Momentum is different than inertia. Inertia says that an object at rest will stay at rest or an object in motion will stay in motion until acted upon by an outside force. Inertia is related to the mass of the object. Momentum is a product of both the mass and velocity of an object. Anything with mass will have inertia, but momentum can be zero if the velocity is zero. We are not concerned with the momentum of a vehicle with no motion, but drivers must be very concerned about the momentum they and their vehicles have. Since momentum is conserved, when a vehicle comes to a sudden stop the passengers will keep moving in the same direction unless something (such as their seat belt) reduces their velocity before they impact something that will injure them.



Section 2 – Screen 9

This screen will allow the student to see what happens to the cake when the skateboard it is riding on suddenly stops. In this scenario, the cake is a substitute for an unrestrained driver in a vehicle that comes to a sudden stop. Since the cake has both mass and velocity, it has momentum and since it has mass, it will resist a change in motion. When the skateboard stops (instantaneously in this case), the cake will continue forward with the essentially the same momentum. Note that in the real world, some momentum would be lost to overcoming the friction with the board.



Section 2 – Screen 10

On this screen the cake continues in motion with the same mass and velocity, thus momentum is conserved. This leads us to Unbreakable Law Number 2.



Section 2 – Screen 11

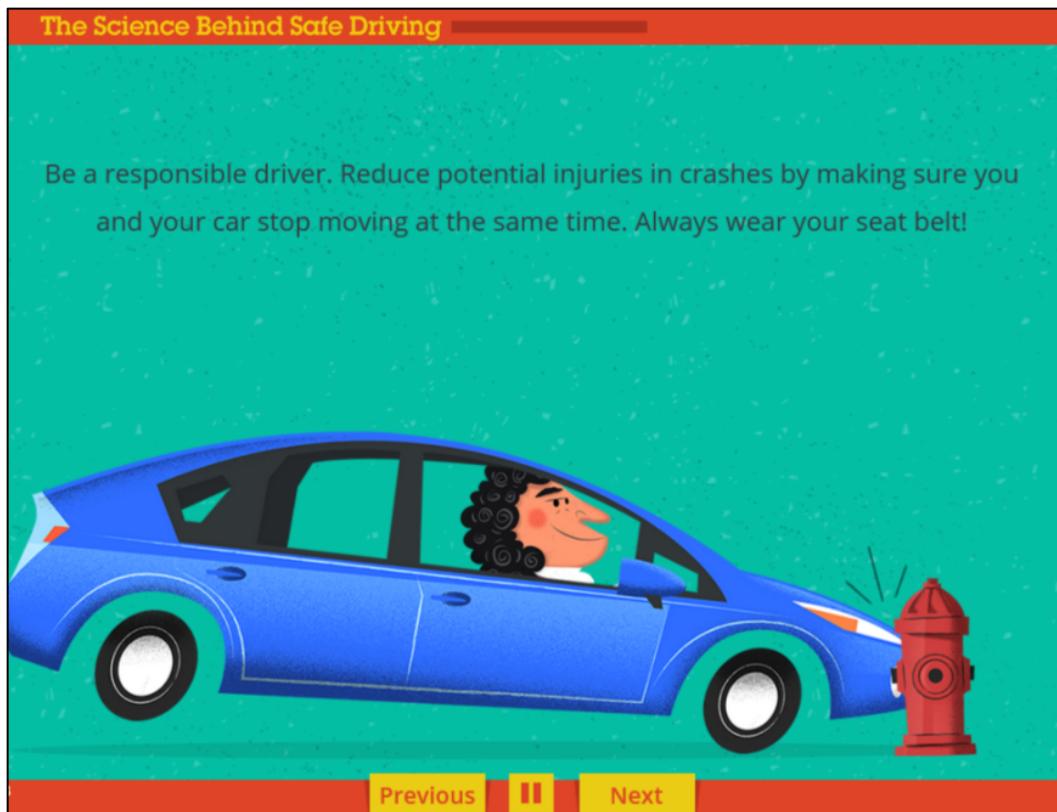
The Law of Conservation of Momentum is derived from Newton's First Law of Motion, which states that an object moving or at rest will stay that way until it acted upon by an external force.



Section 2 – Screen 12

On this screen, the skateboard is replaced by the car and the cake is replaced by the driver. When the car hits the fire hydrant and comes to an immediate stop, the unrestrained driver continues moving forward. The driver's momentum is conserved and still has both the mass and the velocity that was possessed prior to the vehicle stopping. The student must select which safety features would allow the driver's momentum to be reduced during the crash and drag the choice to the car. These safety features will apply an external force to the driver. Note that students are reminded that all of the safety features on the screen are important, but they should focus on the scenario described to select appropriate safety features.

- **Vehicle Stability Control:** This function is a helpful safety device but will not reduce the driver's momentum.
- **Traction Control:** This function is a helpful safety device but will not reduce the driver's momentum.
- **Tires:** Properly inflated tires are a helpful safety feature but will not reduce the driver's momentum.
- **Seat Belts:** A properly fitted seat belt will reduce the driver's momentum and can help reduce injuries in the event of a collision.
- **Airbags:** Airbags, when working in conjunction with a properly fitted seat belt, will reduce the momentum of the driver.



Section 2 – Screen 13

When students get to this screen, they have successfully determined which safety features can help them reduce the momentum of the driver.

Keys to Safe Driving: ***Proper Positioning of Your Seat Belt, Seat, Mirrors, and Hands***

Positioning the Seat Belt

An essential safety device for every vehicle passenger is the seat belt. Properly worn, the seat belt serves to decrease a passenger's velocity, and thus their momentum, in as safe a manner as is possible. In addition, the seat belt will help keep a passenger inside of the vehicle and its impact absorbing crumple zones. Seat belts save lives. Every person in the car must wear one regardless of age, seating position, or the distance to the destination.

To ensure that you are properly wearing your seat belt, do the following:

1. Sit upright.
2. Pull the seat belt out and across your body. Make sure the belt is not twisted.
3. Position the shoulder belt so that it lies flat between your shoulder and your neck. It should not rest on your neck.
4. Place the lap belt as low as possible across the hips. Do not place the lap belt across your stomach.
5. Push the tab into the buckle. The clicking noise is a confirmation that the seat belt is firmly buckled.
6. Check and adjust the height of the belt as needed

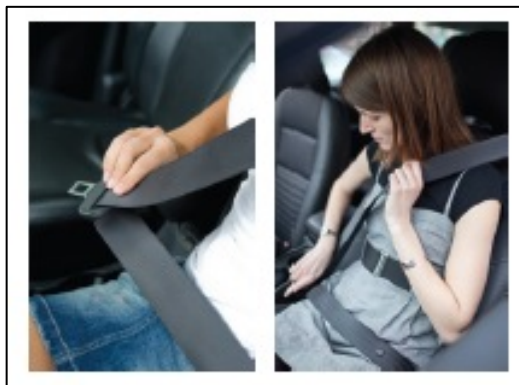


Image from TeenDrive³⁶⁵™ In Dealership TEEN DRIVER SAFETY CLINIC HANDBOOK

Note: Seat belts are designed for adults and older children. Young children should use an appropriate safety system for their age and weight and should be positioned in the rear seat. In cars or trucks where there is no rear seat, children should wear an appropriate safety restraint. In this circumstance, the driver should turn off the passenger airbag, if possible.

Positioning the Driver's Seat, Mirrors, and Hands

Maximizing awareness and control in driving situations is critical to the safety of you and your passengers. Minimize potential distractions by placing your seat, mirrors, and hands in the proper positions to ensure that you can maintain awareness of driving conditions. When your seat, mirrors, and hands are positioned correctly, you are able to see the road and other drivers and better able to spot potential hazards.

To prepare for driving with proper positioning of your seat, mirrors, and hands, do the following:

1. Adjust the driver's seat and steering wheel so you have a slight bend in your elbows and knees.



Image from TeenDrive³⁶⁵™ In Dealership TEEN DRIVER SAFETY CLINIC HANDBOOK

2. Make sure all mirrors are appropriately adjusted for your line of sight. Adjust side mirrors to eliminate "blind spots." Position your rear view mirror so you are able to see the road behind you with only a slight turn of your head.



Image from TeenDrive³⁶⁵™ In Dealership TEEN DRIVER SAFETY CLINIC HANDBOOK

3. Place your hands on the steering wheel at the 9 o'clock and 3 o'clock positions.
4. You should always grip the steering wheel from the outside of the wheel. Do not drive with your hands on the inside or hooked on the bottom of the steering wheel.



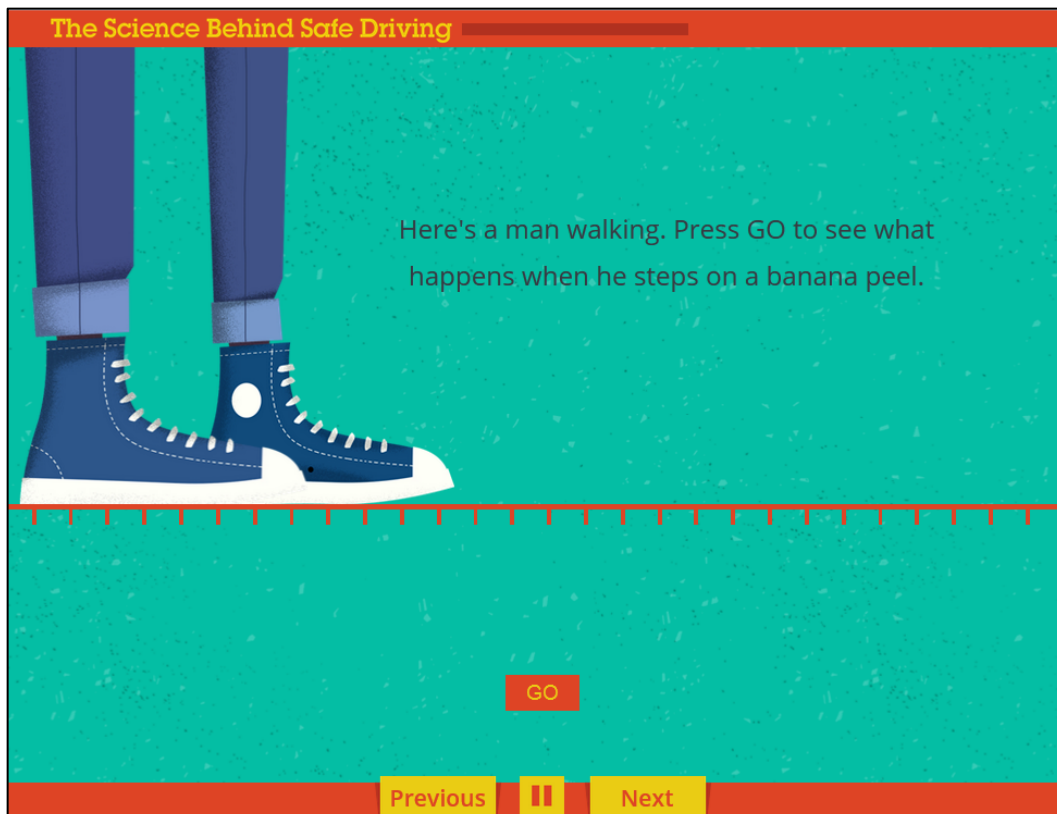
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Section 2: The Laws of Motion and Driving
Driving Laws You Can't Break – Friction



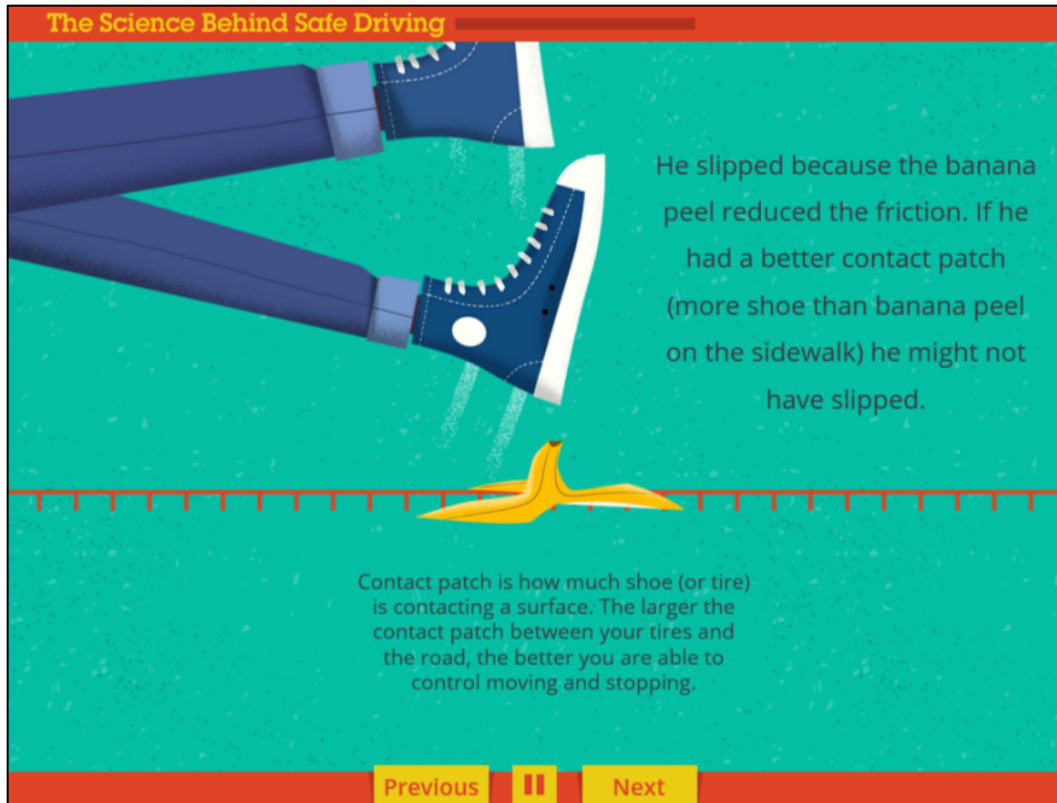
Section 2 – Screen 14

In this section, students investigate friction. In a vehicle, the point of friction is the tires on the road. If the wheels are rolling, the tires will have a *static friction*; the portion of the tire in contact with the road is instantaneously at rest with respect to the road. If the tires lock and the car begins to slide, this would be *kinetic friction*. In general, the coefficient of friction, the ratio of the frictional resistance force to the normal force, is greater for static friction than for kinetic friction. In layman's terms, keeping the tires rolling is the best way to keep you from sliding all over the place!



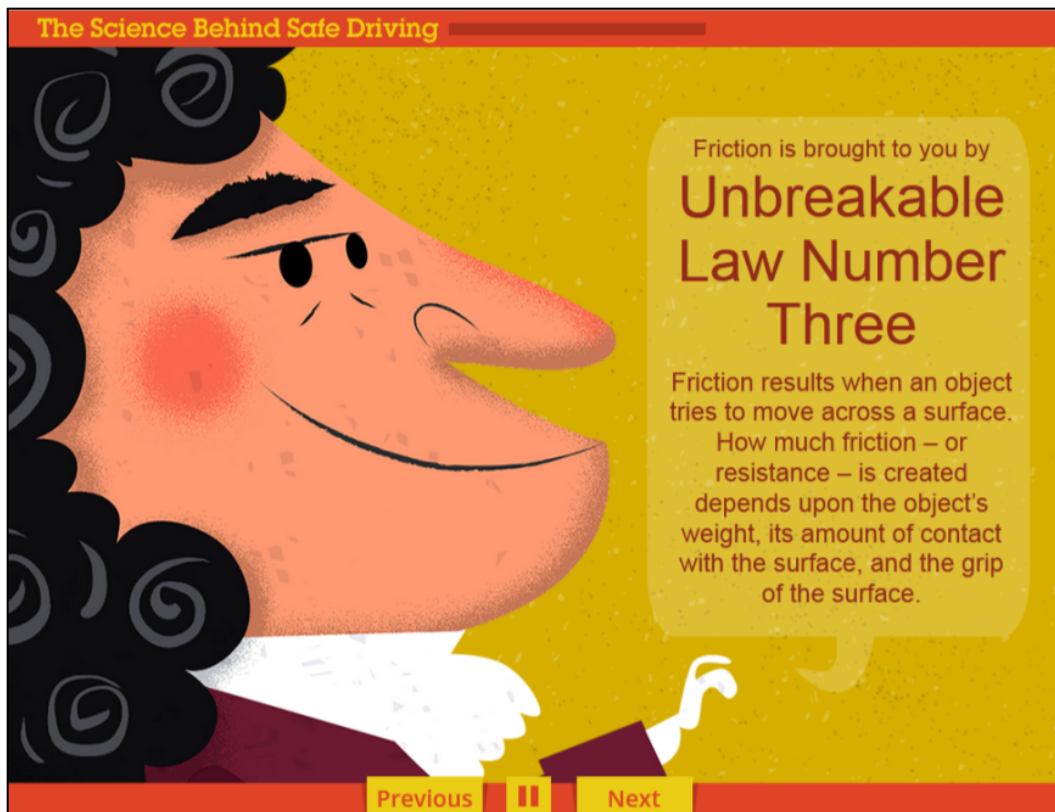
Section 2 – Screen 15

Here, the students begin to explore what happens when the *static friction* provided by the sole of a shoe is replaced with the *sliding friction* of a banana peel.



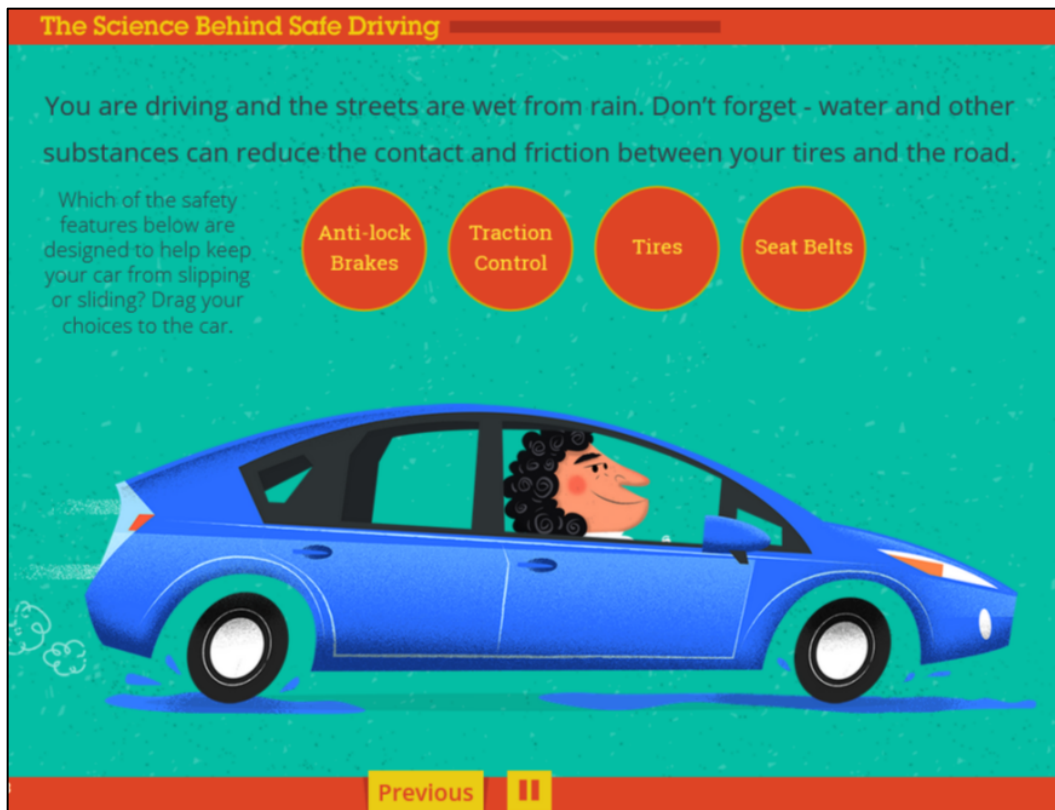
Section 2 – Screen 16

The student sees the results of the change from static friction to kinetic friction. Tires are designed to have a contact patch that provides adequate surface area to maintain static friction and treads to help prevent hydroplaning by channeling water away.



Section 2 – Screen 17

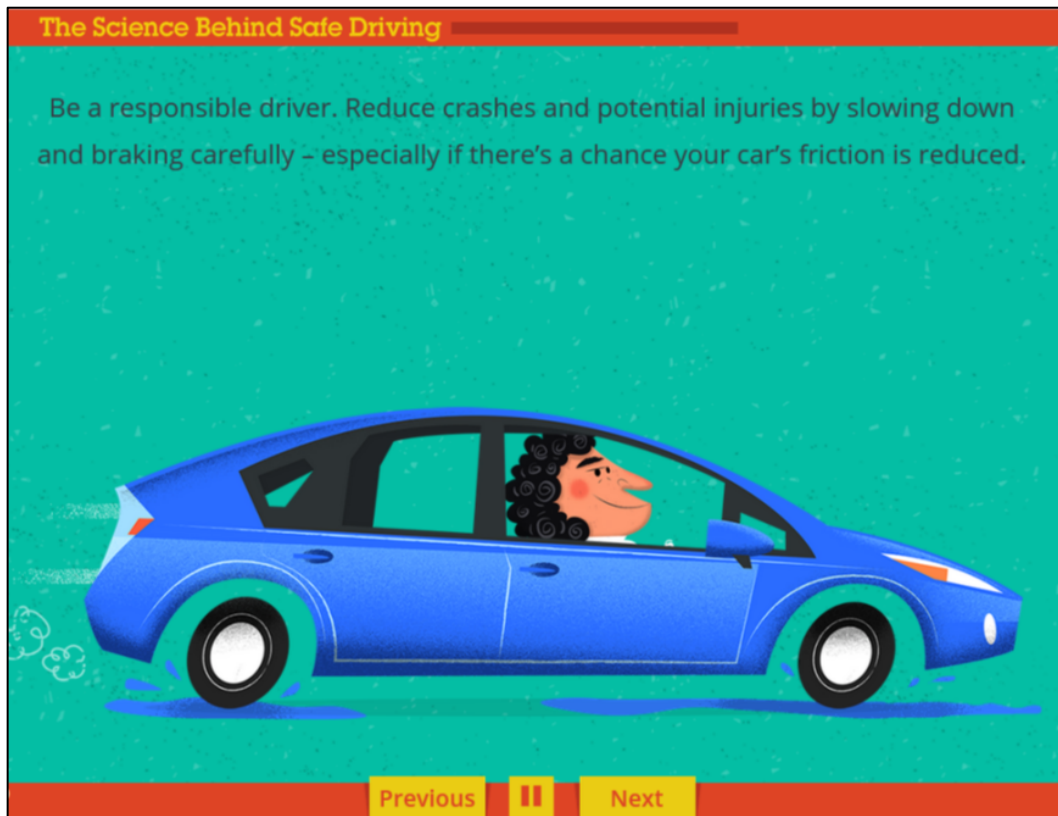
Students learn that the amount of friction between an object and a surface is dependent on the weight of the object, the amount of contact the object has with the surface, and the grip of the surface. In the standard model of friction, friction is independent of surface area. There are, however, many exceptions – and this is one of them! The grip of the surface depends on the type of material the surface is made of and, particularly in driving scenarios, if the surface is dry, wet, gravelly, or icy.



Section 2 – Screen 18

On this screen, students explore how various safety features affect the friction that holds the car on the road.

- **Electronic Brake Force:** This is an electronic device on your car that varies the braking force, which may help your car stop more efficiently in some driving situations.
- **Anti-Lock Brakes:** When the wheel start to lock up on a slippery surface the ABS pulses the brakes to keep the tires rolling. This helps keep the tires in static friction with the road and keeps you in control.
- **Traction Control:** Traction control senses wheels spinning and reduces engine power and applies the brakes to re-establish contact with the surface. This will help you maintain control of your vehicle
- **Tires:** Tires with good tread depth (at least 2/32 of an inch) and properly inflated tires will increase the chance of a good contact patch with the road.
- **Seat Belts:** While seat belts are an important safety feature, they will not help prevent your car from slipping or sliding.



Section 2 – Screen 19

Student will see this screen when they have successfully chosen the correct safety features that will help prevent slipping and sliding.

Keys to Safe Driving: *Checking Your Tires' Tread and Air Pressure*

Tires with good tread depth (at least 2/32 of an inch) and properly inflated tires will increase the chance of a good contact patch with the road. You can check your tire tread using a tire tread depth gauge.

For most tires, you can also check your tread depth using a Lincoln penny. If you can see the top of Lincoln's head, it is time for new tires!

Additionally, many tires have built-in tread wear indicators. They are usually invisible, but will appear across treads that have been worn to a depth of 1/16 of an inch.

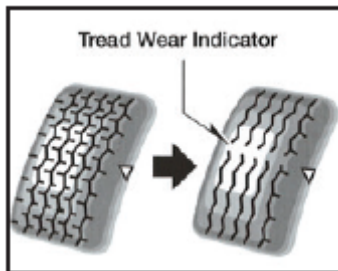


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Checking Your Tires' Air Pressure

Proper tire inflation is important. If tire pressure is too low, the tire bows and reduces the contact patch. If tire pressure is too high, the tire bulges and reduces the contact patch. Follow the manufacturer's recommendation for tire load and tire pressure to insure that your car has the optimum contact patch.

To check the tire pressure of your car, use the following procedure:

1. Check your owner's manual or the sticker on the doorjamb for the optimum cold tire pressure. Be aware that the pressure may be different for the front and rear wheels and for the spare tire. (Note: Check the air pressure on your spare tire regularly to ensure it is ready to use in case of an emergency.)
2. Make sure to check tire pressure when your tires are cold. As you drive on tires, the air inside them heats up and expands, increasing the pressure.
3. Use an accurate pressure gauge. Do not depend on the air gauge on the compressor at your local service station.



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4. Add or release air from the valve stem each tire's pressure matches the recommended pressure.
- Add pressure by putting the air nozzle over your tire stem. You should hear air going into the tire.
 - To let air out, press down on the needle in the middle of the valve. Most pressure gauges have a small knob for this.

Important Note: Tires should not intentionally be under- or over-inflated. This does not increase contact patch and can actually lead to tire failure! The graphic below shows how under- and over-inflation affects the tire's contact patch.

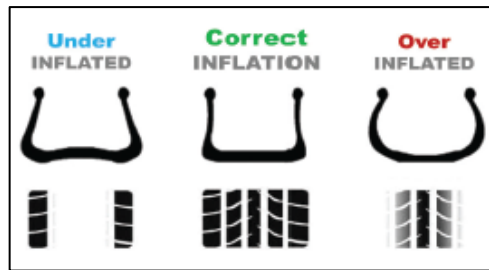
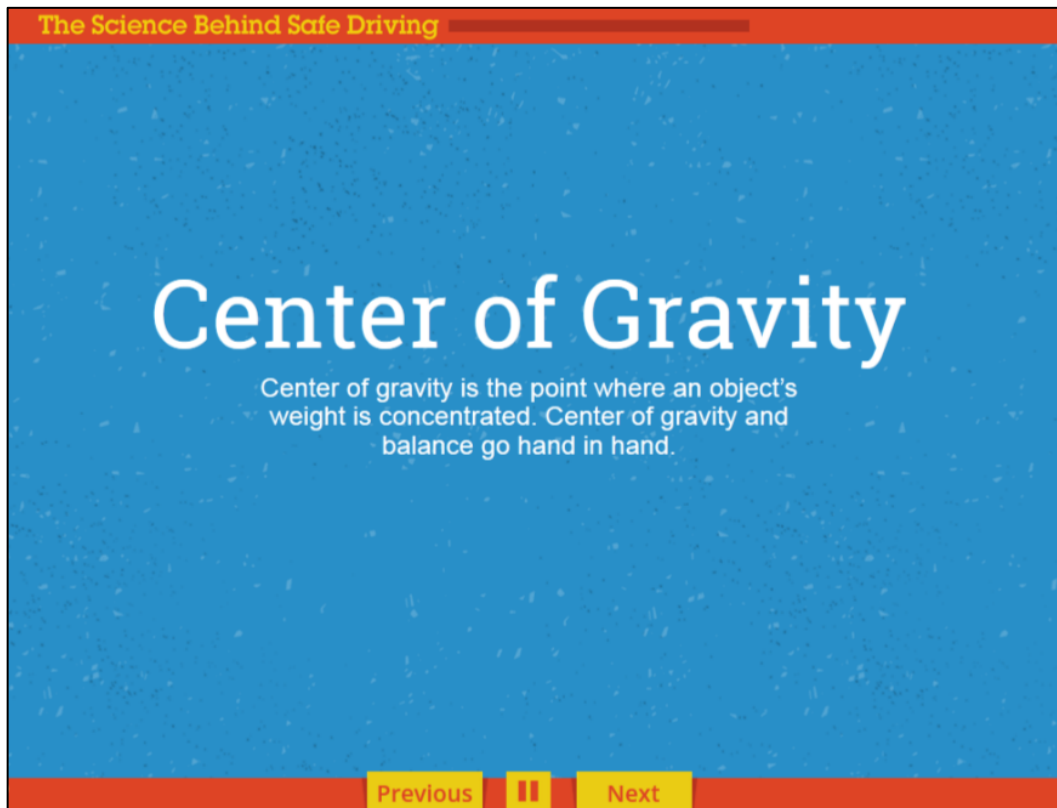


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Section 2: The Laws of Motion and Driving
Driving Laws You Can't Break – Center of Gravity



Section 2 – Screen 20

The center of gravity is the average location of weight for an object. In this section, students investigate how changes in speed, weight, and direction can affect the center of gravity – and thus the stability – of their vehicle.



Section 2 – Screen 21

On this screen, students experiment with a top-heavy shopping cart and different types of curves. Since most of the weight of the shopping cart is elevated, its center of gravity is higher than halfway up from the base.



This shopping cart is stacked high with heavy boxes. What happens if you give the cart a hard shove around these curves?



Click each curve to see how each affects the cart's balance.

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This shopping cart is stacked high with heavy boxes. What happens if you give the cart a hard shove around these curves?



Click each curve to see how each affects the cart's balance.

Previous



Next

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This shopping cart is stacked high with heavy boxes. What happens if you give the cart a hard shove around these curves?



Click each curve to see how each affects the cart's balance.

Previous



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As the curves got sharper, it was increasingly difficult for the wheels to pull the cart's center of gravity around the turn. On the sharpest turn, this pull – combined with the top-heavy load – shifted the cart's center of gravity outward enough to tip the cart over.

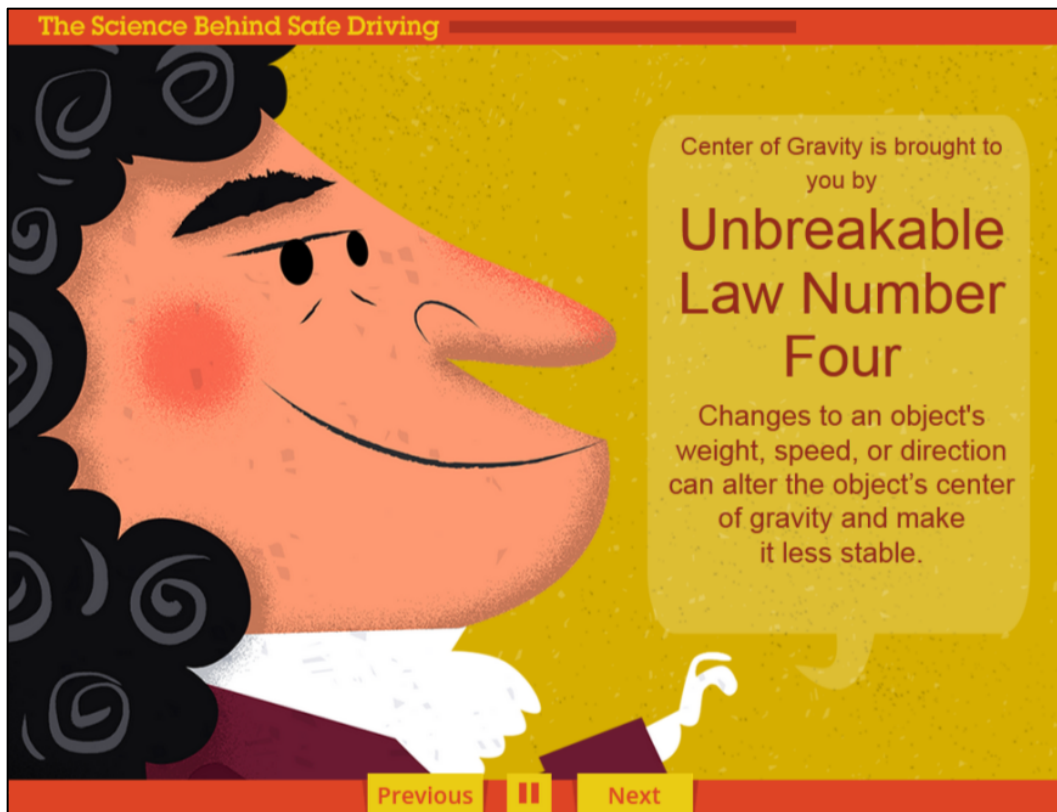


Friction also plays a role in keeping the cart safely on the ground. However, if the center of gravity shifts enough, the frictional force on the wheels won't be enough to keep the cart upright!

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Section 2 – Screen 22

Students see the results of moving a top-heavy vehicle (whose center of gravity has been raised) around various curves. Emphasize to students that, even if the vehicle doesn't tip over, instability is dangerous. Instability may cause the driver to overreact, leading to loss of control, sliding, or even vehicle rollover.



Section 2 – Screen 23

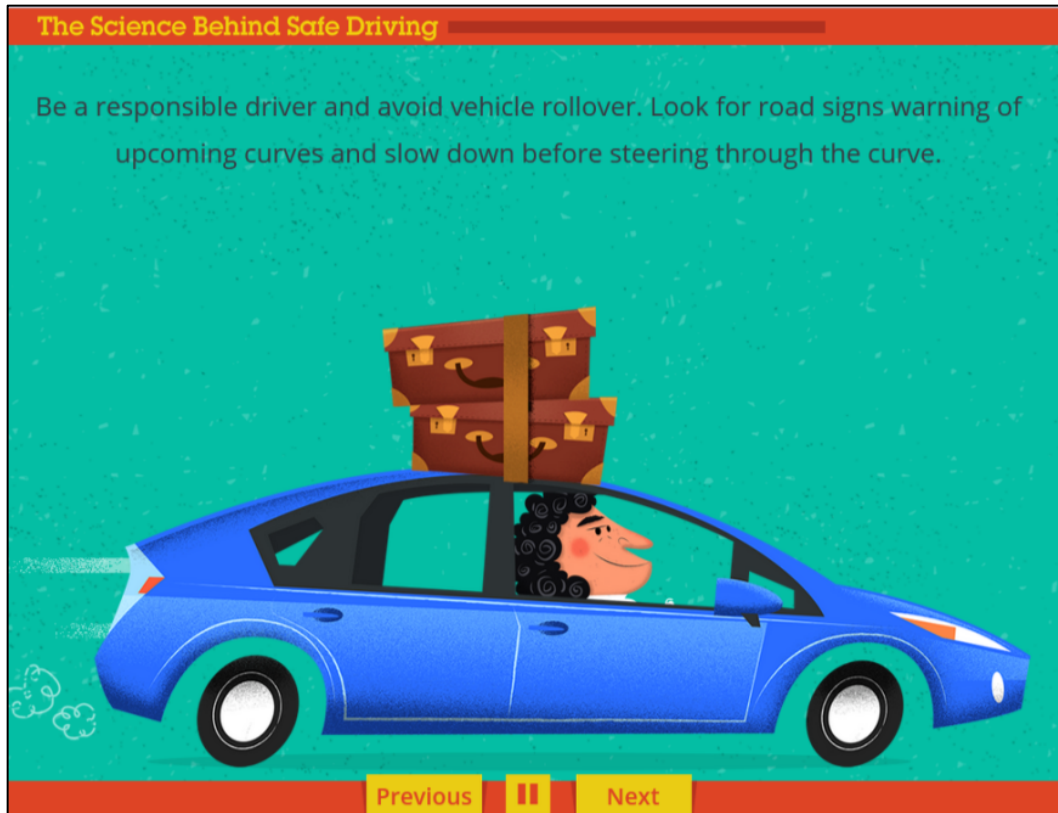
If an object's center of gravity changes, the object may become unstable.



Section 2 – Screen 24

On this screen, students explore the safety features that affect center of gravity and prevent sliding and tipping over. They drag the appropriate choices to the car. Note that students are reminded that all of the safety features on the screen are important, but they should focus on the scenario described to select appropriate safety features.

- **Tires:** Tires with proper inflation and tire tread result in less slipping and sliding.
- **Vehicle Stability Control:** Vehicle stability control helps prevent side skids and help stabilize the vehicle while turning on a curve.
- **Seat Belts:** Seat belts are an important safety device but will not help prevent skidding or tipping over.
- **Air Bags:** Air bags are an important safety device but will not help prevent skidding or tipping over.



Section 2 – Screen 25

Student will see this screen when they have successfully selected the safety devices that will reduce skidding and rollover.

Section 3: The Best Safety Feature is YOU

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The Best Safety Feature is You

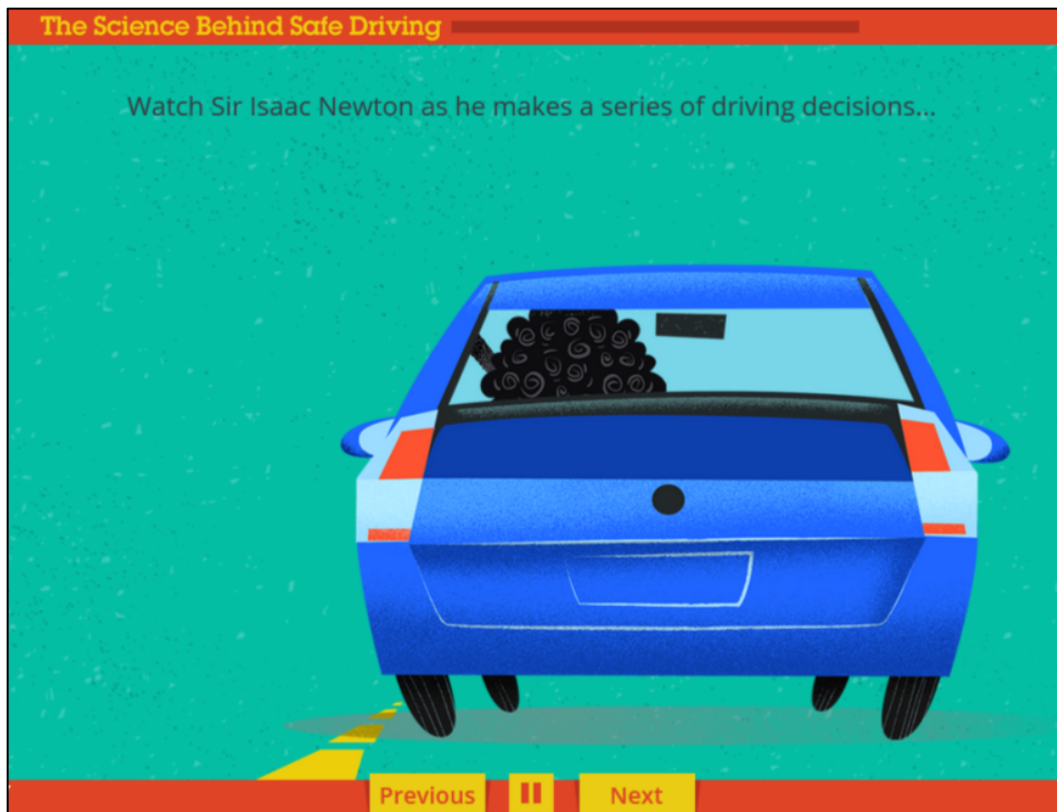
You've learned how four laws of physics are in constant play while you're behind the wheel. You've also reviewed a lot of car safety features that help keep you safe when you drive.

But a car's very best safety feature is you. The decisions you – the driver – make are the most important factor in reducing crashes and potential injuries.

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Section 3 – Screen 26

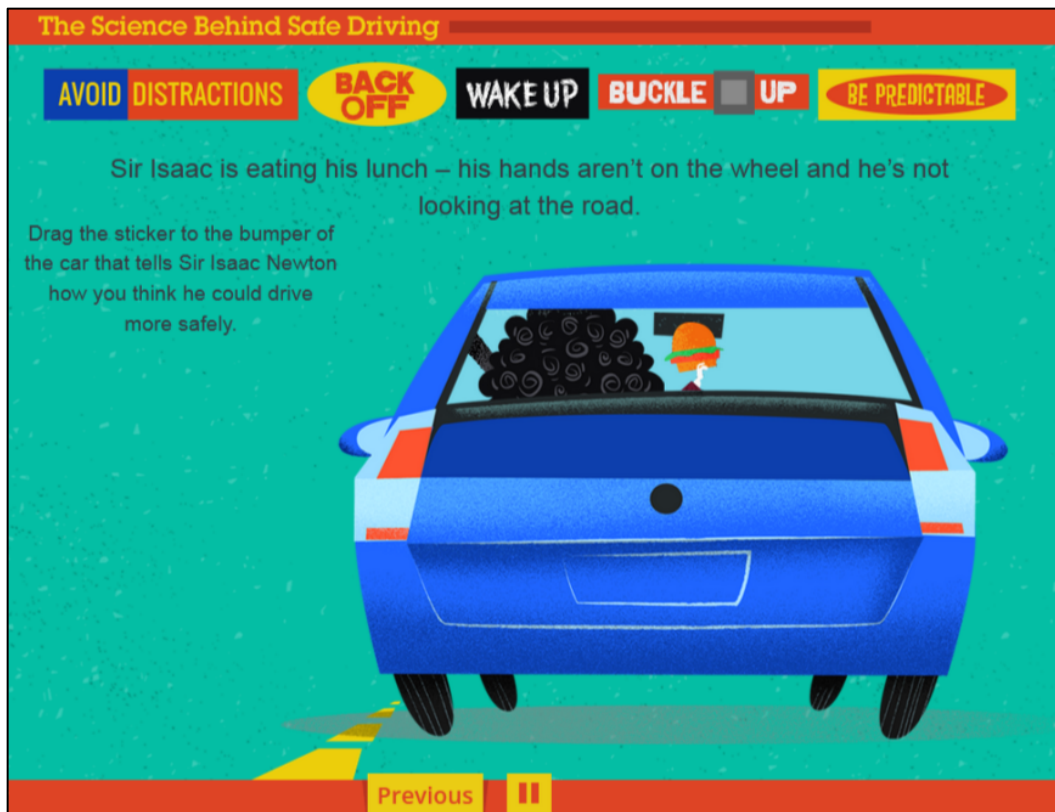
Safety devices are important and necessary but nothing is more important than the decisions made by the driver.



Section 3 – Screen 27

On this screen, students are directed to observe the driving decisions of a fictionalized character.

Note to the Teacher: Consider discussing with students the concept of *illusory superiority*. Illusory superiority is a common cognitive bias in which people consider their own skills or intelligence as superior to the skills or intelligence of others. In driving, this manifests as people believing they are much better drivers than those around them. This, unfortunately, can result in a resistance to driving instruction and/or a lack of willingness to examine one's own driving decisions and behaviors.



Section 3 – Screen 27

In this section, students are presented with a number of inappropriate driving behaviors, such as “Sir Isaac is eating his lunch--not looking at the road.” Students choose the appropriate behavior (via bumper sticker) to correct the behavior. In this case, students should choose the bumper sticker that reads “Avoid distractions.” The following are the other inappropriate driving behaviors presented in this section (and the appropriate driving behavior students should select):


- Sir Isaac made a lane change but no blinker.
 - Bumper sticker: Be predictable.
- Sir Isaac is following that car way too closely.
 - Bumper sticker: Back off.
- Sir Isaac is falling asleep.
 - Bumper sticker: Wake up.
- Sir Isaac forgot to fasten his seat belt.
 - Bumper sticker: Buckle up.

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AVOID **DISTRACTIONS** **BACK OFF** **WAKE UP** **BUCKLE UP** **BE PREDICTABLE**

Sir Isaac forgot to fasten his seat belt.

Drag the sticker to the bumper of the car that tells Sir Isaac Newton how you think he could drive more safely.




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The Science Behind Safe Driving

AVOID **DISTRACTIONS** **BACK OFF** **WAKE UP** **BUCKLE UP** **BE PREDICTABLE**

Sir Isaac is following that car way too closely.

Drag the sticker to the bumper of the car that tells Sir Isaac Newton how you think he could drive more safely.



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The Science Behind Safe Driving

AVOID DISTRACTIONS


BACK OFF

WAKE UP

BUCKLE UP

BE PREDICTABLE

Sir Isaac made a lane change but no turn signal.



Drag the sticker to the bumper of the car that tells Sir Isaac Newton how you think he could drive more safely.

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II

The Science Behind Safe Driving

AVOID DISTRACTIONS

BACK OFF


WAKE UP

BUCKLE UP

BE PREDICTABLE

Sir Isaac is falling asleep.

Drag the sticker to the bumper of the car that tells Sir Isaac Newton how you think he could drive more safely.



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Section 3 – Screen 28

Students will reach this screen when they have successfully matched the inappropriate driving behavior with the correct bumper sticker (appropriate driving behavior).

Section 4: Checking Understanding



Section 4 – Screen 29

The activity ends with a five-question check for understanding. See below for questions and answers.

The Science Behind Safe Driving

If you suddenly hit the brakes,
your seat belt will...

- A. reduce the forward momentum of your body
- B. help you decelerate in sync with your car
- C. keep you in your seat during an impact
- D. All of the above

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Correct Answer: D

Choices A, B and C are all true statements, so D is the best choice.

When you strap a heavy load on top of your car, you...

A. compromise your anti-lock brakes

B. raise the car's center of gravity

C. cause deflation in your tires

D. All of the above

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Correct Answer: B

Anti-lock brakes are not affected by loads on top of the car and heavy loads will not deflate tires. B is the correct answer as the center of gravity rises.

Friction between your tires and the road can be reduced by...

A. wet driving conditions

B. worn tire treads

C. improper tire inflation

D. All of the above

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Correct Answer: D

Answers A, B and C can all reduce friction.

Which of these features helps you safely stop the car?

A. Windshield wipers

B. Anti-lock brakes

C. Airbags

D. Seat belts

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Correct Answer: B

Airbags and seat belts are restraint systems and like windshield wipers to clear rain and snow are important to driver safety. However, none of those choices - A, C, or D – will help the car stop safely.

What can you do to be a safe driver?

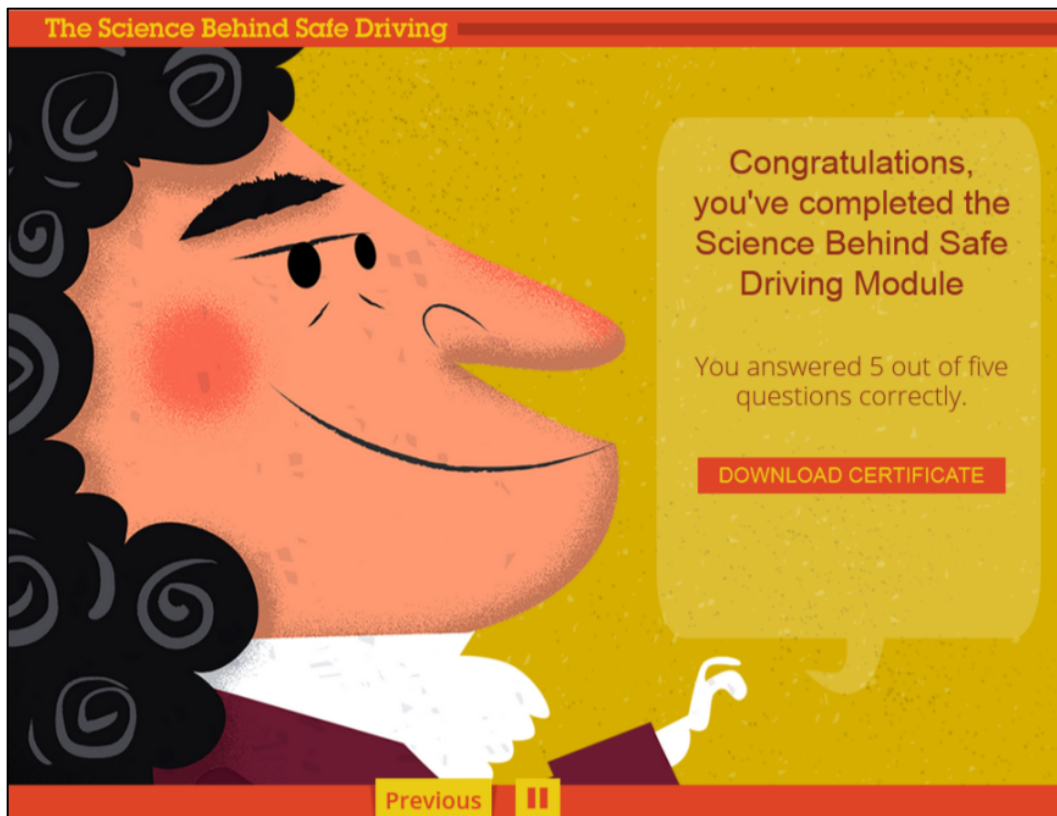
- A. Check tires for proper pressure and tread
- B. Properly use your seat belt – both shoulder belt and lap belt
- C. Stay aware of road conditions and other drivers
- D. All of the above

Previous



Correct Answer: D

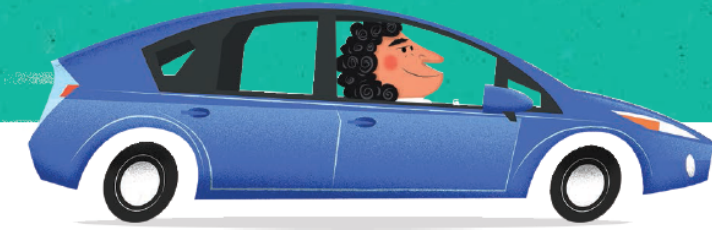
Answers A, B, and C are all steps that a driver can take to be safe.



Section 4 – Screen 30

Students are congratulated for completing the module and may download a Certificate of Completion.

Certificate of Completion



_____ has successfully completed the
Toyota TeenDrive365 Science Behind Safe Driving Module

Date

Teacher or Parent

In this interactive learning module, you explored the relationships between fundamental principles of physics, vehicle safety features, and smart, safe driving habits. Most importantly, you learned that the best safety feature is YOU and that you have the power and responsibility to make decisions that will help keep you safe behind the wheel.

