To the local council. Project Lead the Way has graciously allowed the Boy Scouts of America to utilize a handful of its IndyCar-related STEM curriculum activities for use by local councils at IndyCar events. Here are some tips on using these activities at your local IndyCar race:

- Review the 5 activity outlines for feasibility at your local IndyCar race
- Obtain a map of the program area dedicated to your STEM activities from the BSA contact person at your local race track (square footage, foot traffic flow, etc)
- Recruit a sufficient number of volunteers to lead each activity, in shifts if needed
- Confirm set up and tear down dates and times with the race track
- Utilize the customizable BSA Racing social media images, email template and fliers to promote this opportunity to Scouts, families and volunteers available at www.scouting.org/resources/bsa-racing
- Take lots of pictures and share your event success stories with the BSA Foundation by completing the online form at www.scouting.org/resources/bsa-racing

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Future of Fast Car Pod: Wind Tunnel

Teacher Instructions (Student Instructions at Bottom)

Introduction

An INDYCAR race vehicle reaches speeds well over 200 miles per hour. This makes tire traction crucial to vehicle control. Fortunately the high speed can be used to push the car into the track using specially designed wings. Such wings use the same lift principle that allows aircraft to fly. The difference is that IndyCar uses an inverted lift principle, which forces the car down rather than lifting it up.

In this activity students will measure the performance of a model INDYCAR wing in a wind tunnel.

Equipment

<table>
<thead>
<tr>
<th>Materials Needed for Setup</th>
<th>Materials Needed for Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 3/32” Hex key to tighten button head socket cap screw</td>
<td>1. Wind tunnel with INDYCAR wing model</td>
</tr>
<tr>
<td>2. (2) Adjustable wrenches or 11/32 in. wrench</td>
<td>2. 9/64” Hex key to adjust socket head cap screw if needed</td>
</tr>
<tr>
<td>3. Power strips (1 per group of 4)</td>
<td>3. Pens (2 per team)</td>
</tr>
<tr>
<td>4. Battery backups for scale (3 AAA per scale)</td>
<td>4. Future of Fast Car Pod: Student Data Sheet (1 per team expected)</td>
</tr>
</tbody>
</table>
Procedure for Pod Setup

1. Set up pod according to pod map.

   ![Pod Diagram]

   Pod is 30 ft inscribed hex
   Scale: 1 in. = 4 ft

2. Place the materials shown on the list above for each team. Two teams share each table.

3. Plug in wind tunnels to power strips (1 per group of 4) and confirm that the wind tunnel functions by rotating fan speed dial to position 1, 2, then 3.

4. If the wind tunnel side walls are not attached, install using the image below for guidance.
5. Test to ensure that the scale functions.
   a. Power the scale on by pressing the power button on the left.
   b. The scale should read zero or close to it.
   c. Confirm that units are set to grams.

6. Make sure the screws that hold down the scale are not exerting force on the top of the scale. Push on the top of the scale and then release all contact with the scale. The scale reading should increase and then return to zero.

7. The three AAA batteries used to power the scale will last a long time since the scale automatically shuts off after three minutes without activity. To change the battery, use the procedure below.
   a. Tip the wind tunnel up to access the scale battery compartment.
   b. Remove the battery compartment cover.
   c. Change the three AAA batteries.
8. Select a NEGATIVE angle of attack less than 20 degrees. Follow the student procedure to measure and record the scale value at a fan speed of #3 (28.6 mph). This value will be used later to prepare a challenge for teams. Below are example measurements.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Fan speed #3 Scale Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (m/s)</td>
<td>12.8</td>
</tr>
<tr>
<td>Speed (mph)</td>
<td>28.6</td>
</tr>
<tr>
<td>-30</td>
<td>108</td>
</tr>
<tr>
<td>-25</td>
<td>102</td>
</tr>
<tr>
<td>-20</td>
<td>98</td>
</tr>
<tr>
<td>-15</td>
<td>84</td>
</tr>
<tr>
<td>-10</td>
<td>66</td>
</tr>
<tr>
<td>-5</td>
<td>48</td>
</tr>
<tr>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>-12</td>
</tr>
<tr>
<td>20</td>
<td>-20</td>
</tr>
<tr>
<td>25</td>
<td>-18</td>
</tr>
<tr>
<td>30</td>
<td>-14</td>
</tr>
</tbody>
</table>
Procedure for Activity

0:00 – 3:00 Minutes

Students

1. Divide students into 4-person teams using a teacher preferred method. You may choose to have students count off 1 through 4, repeating until all students have been assigned to one of eight teams. All eight teams will complete the learning activity simultaneously.

2. Introduce activity using questions below.
   1. What school is this group from?
      Establish rapport with the students
   2. Who has seen an IndyCar race live? On TV?
      Establish rapport with the students
   3. How fast does an IndyCar travel?
      Speeds approach 260 mph. Slower for street races (i.e., 180 mph)
   4. What is the main thing that allows the driver to control the vehicle?
      Tire contact with track surface
   5. What two things improve traction or grip of IndyCar tires?
      Coefficient of friction (tire material, temperature, track conditions, etc.) and weight on tires
   6. How much does an IndyCar vehicle weigh
      Approximately 1600 lb (1575 lb on road, street, or short oval and 1545 lb on speedways)
   7. How can the weight on the tires be increased?
      Generate down force aerodynamically
   8. Ever stuck your hand out of the window of a moving car?
      Lots of hands should go up
   9. What happens when you move your hand up and down?
      Aerodynamic force is what causes your hand to move up and down
   10. Should IndyCar wing surfaces tilt up or down?
      Use hand to demonstrate what will cause lift (arm up) and down force (arm down)
   11. IndyCar race cars possess multiple aerodynamic surfaces to create down force. How many aerodynamic surfaces does an IndyCar have?
      a. Front wings, rear wing, and main body
      b. Main body produces the majority of down force, approximately 2,000 lb
      c. Front and rear wings provide tuning based on driver preference (e.g., front and rear tire traction, grip preference, etc.).
   12. Announce the challenge: The team race engineers need a down force of 84 grams at fan speed #3 (28.5 mph). At what angle of attack does the team need to set the wing?
      Teams need to measure that value (answer will be -15 degrees)
   13. Note: Avoid showing Professor B on Dirty Air because it displays older IndyCar vehicles: http://www.youtube.com/watch?v=RIQ4yWVWhY

3:00 – 7:00 Minutes

Teacher

1. Demonstrate as students mimic a wing test procedure starting at step 3 of the student instructions below.
   Measure scale at an angle of attack of zero through -10 degrees or until students are able to continue on their own. Below are the general steps:
   1. Set angle to zero. Warn student to avoid over-tightening the set screw.
   2. Verify that scale units are grams.
   3. Zero the scale.
   4. Set fan speed to #3.
   5. Record scale value.
   6. Move the wing to -5 degrees angle of attack. Do this by moving the trailing edge, NOT the set screw.

2. Announce that students are to:
   1. Continue to make measurements up to -30 degrees.
   2. Measure positive angle of attack.
   3. Draw graph.
   4. Prepare answer for angle setting.
7:00 – 17:00 Minutes
Students
Gather data and prepare to answer angle setting challenge.

Teacher
Monitor students and assist as needed.
Confirm that both the data and graph are reasonable. An example is shown below.

![Graph showing speed vs. angle of attack](image)

17:00 – 20:00 Minutes
Students
Participate in a reflection discussion.

Teacher
Lead a reflection discussion using the points below for guidance:
1. At what angle of attack does the team need to set the wing to create a down force of 84 grams at fan speed #3 (28.5 mph).
   -15 degrees
2. How is the angle of attack important?
   Angle of attack will change the down force on the car and tires.
3. What will happen at higher speeds?
   Down force will increase with speed.
4. What is happening at an angle setting of +10 degrees?
   The wing generates enough lift to support its own weight.
5. What is happening at an angle setting of +15 degrees?
   The wing stalls where flow separates from the wing, and most of the lift is lost.

20:00 Minutes
Students
Move to next activity.

Professional Development Opportunities
1. Professor B on Dirty Air - [http://www.youtube.com/watch?v=RIQ4yWVWhY](http://www.youtube.com/watch?v=RIQ4yWVWhY)
Future of Fast Car Pod Student Instructions

Introduction

An INDYCAR race vehicle reaches speeds well over 200 miles per hour. This makes tire traction crucial to vehicle control. Fortunately the high speed can be used to push the car into the track using specially designed wings. Such wings use the same lift principle that allows aircraft to fly. The difference is that IndyCar uses an inverted lift principle, which forces the car down rather than lifting it up.

In this activity students will measure the performance of a model INDYCAR wing in a wind tunnel.

Procedure

1. Pick your role within the team:
   a. Race Engineer: Records the down force values and draws the graph.
   b. Data Acquisition Engineer: Reads the scale values.
   c. Wing Technician #1: Adjusts the wing angle at the front of the scale.
   d. Wing Technician #2: Verifies the wing angle at the rear of the scale.

2. Go to your assigned position around the wind tunnel as shown below.
3. The Wing Technician #1 ensures that the fan is pointing straight into the wind tunnel by pushing down on the front of the fan gently. Set the wing angle of attack to zero. You might need to loosen the socket head cap screw.

4. If the scale is powered off, then the Data Acquisition Engineer presses the power button on the right of the scale and confirms that it is set to measure in grams. Note that the scale value can be positive or negative.

5. The Data Acquisition Engineer presses the 0.0 Tare button to set the scale to zero. Verify that the scale value shows zero and that it is measuring in grams.

6. The Wing Technician #1 turns the fan settings to level 3. This will generate a wind speed of approximately 28.6 mph.

7. The Data Acquisition Engineer informs the Race Engineer of the scale value at the setting for recording, including whether it is positive or negative. For now this value should be positive.

8. The Wing Technician #1 adjusts the angle of attack to -5 degrees while Wing Technician #2 adjusts to the same setting. The Data Acquisition Engineer informs the Race Engineer of the scale value to record. Refer to the images below to set a positive and negative angle of attack.
9. The Wing Technician #1 and #2 adjust the angle of attack by -5 degrees up to -30 degrees. The Data Acquisition Engineer informs the Race Engineer of the scale value at the setting for recording at each angle.

10. The Wing Technician #1 and #2 adjust the angle of attack to 0 degrees. The Data Acquisition Engineer and Race Engineer verify that the value matches what was recorded earlier.

11. The Wing Technician #1 and #2 adjust the angle of attack to +5 degrees. The Data Acquisition Engineer and Race Engineer record the scale value.

12. The Wing Technician #1 and #2 adjust the angle of attack by +5 degrees up to +30 degrees. The Data Acquisition Engineer and Race Engineer record the scale value each time. Remember to record whether the value is positive or negative.

**Stop Here Unless Extra Time is Available**

13. The Wing Technician #1 turn the fan settings to level 2. This will generate a wind speed of approximately 28 mph.

14. Repeat the steps above. Record the values at each 5 degree angle setting.

15. The Wing Technician #1 turn the fan settings to level 1. This will generate a wind speed of approximately 26.8 mph.

16. Repeat the steps above. Record the values at each 5 degree angle setting.

17. The Race Engineer draws a graph of the data.

18. The Race Engineer leads the team discussion of the results. All team members agree on the recommended angle setting to produce a down force of ___ grams at ____ mph.
Future of Fast Car Pod Student Data Sheet

The team recommends an angle of ______ degrees to produce a down force of ______ grams.

**Down Force Measurements**

<table>
<thead>
<tr>
<th>Angle of Attack (Degrees)</th>
<th>Scale Value (Grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td></td>
</tr>
<tr>
<td>-25</td>
<td></td>
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<tr>
<td>-20</td>
<td></td>
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<td>-10</td>
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<tr>
<td>+5</td>
<td></td>
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<td>+10</td>
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<tr>
<td>+15</td>
<td></td>
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<tr>
<td>+20</td>
<td></td>
</tr>
<tr>
<td>+25</td>
<td></td>
</tr>
<tr>
<td>+30</td>
<td></td>
</tr>
</tbody>
</table>

**Down Force Graph**

![Graph showing down force measurements in degrees and grams.]

Staples receipt attached earlier
Future of Fast Engine Pod: Human Horsepower

Teacher Instructions (Student Instructions at Bottom)

Introduction
Have you heard a car commercial claim that a vehicle has 185 horsepower and wondered what that means? How is horsepower determined? How is a car related to horses?

The Scottish engineer and inventor James Watt is credited with crafting the term “horsepower” in the 18th century. He wanted a unit of measurement that could compare the power of a steam engine to a horse. Mr. Watt calculated that one of his ponies could generate 22,000 foot-pounds of work in a minute while lifting coal from a mine. He increased the calculation by 50%, thus establishing 33,000 foot-pounds of work per minute as the unit we call horsepower.

In this activity students will determine how much horsepower individuals on a team produce and then calculate the total horsepower of the team. Students will also compare their total horsepower to INDYCAR engines.

Equipment

<table>
<thead>
<tr>
<th>Materials Needed for Setup</th>
<th>Materials Needed for Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Honda replica engine (provided by Honda)</td>
<td>1. Pen (2 per team)</td>
</tr>
<tr>
<td>2. 12 ft Carpet runner (3)</td>
<td>2. Clipboard (1 per team)</td>
</tr>
<tr>
<td>3. Carpet tape</td>
<td>3. Calculator (1 per team)</td>
</tr>
<tr>
<td>4. Gaffer tape</td>
<td>4. Stopwatch (1 per team)</td>
</tr>
<tr>
<td>5. 5 lb Kettle bell (2)</td>
<td>5. Measuring tape (4 per POD)</td>
</tr>
<tr>
<td>6. 10 lb Kettle bell (1)</td>
<td>6. Future of Fast Engine Pod: Student Data Sheet (1 per team)</td>
</tr>
<tr>
<td>7. 20 lb Kettle bell (1)</td>
<td></td>
</tr>
<tr>
<td>8. Sled (3)</td>
<td></td>
</tr>
<tr>
<td>9. Sled-to-Harness apparatus (3)</td>
<td></td>
</tr>
<tr>
<td>10. 35 lb Weight (3)</td>
<td></td>
</tr>
<tr>
<td>11. Luggage scale (1)</td>
<td></td>
</tr>
</tbody>
</table>

Procedure for Pod Setup by Teacher

1. Set up pod according to the pod map.
   a. The Honda replica engine will be placed for pod atmosphere.
   b. Place a 5 lb and 10 lb kettle bell on opposite ends of one table. Place a 5 lb and 20 lb kettle bell on opposite ends of a second table. Arrange the tables on opposite sides of the pod.
   c. Position the carpet runners to ensure that students have enough room to safely pull the sled.
   d. If needed attach the carpet runners to the floor using carpet tape or landscape spikes.
   e. Place gaffer tape on carpet to indicate the start and stop position separated by 8 ft.
   f. Place the items shown on the materials list at each position (1-7).
2. Prepare the sled.
   a. Thread the small spindle on sled.

   b. Orient the sled pulls to allow students to run past the pod footprint. This will vary based on availability of space. Below is an example.
c. Place the sled at one end of carpet with the front crossbar on the gaffer tape.

Attach the harness-to-step strap without the harness and lay out toward the finish line.
d. Place equivalent of 35 lb weight on the sled’s spindle.

e. Pull the sled while measuring tension with a luggage scale between the harness and your hand. This is the tension to be used by students since it will vary by coefficient of friction between the carpet runner and sled. This should be approximately 10-15 lb and was measured to be 14 lb.

f. Calculate the horizontal tension force using trigonometry. Assume that the angle between the horizontal is 35 degrees for an average student height. This was calculated to be 11.5 lb.

\[
\cos \theta = \frac{b}{c} \\
b = \cos 35\degree \cdot c \\
b = 0.8192 \cdot ____ \text{ lb} \\
b = ____ \text{ lb}
\]

3. Verify that stopwatches are functioning.
Procedure for Activity

0:00 – 2:00 minutes

Teacher

1. Introduce activity using the talking points below for guidance.
   1. What is horsepower?
   2. An IndyCar Series car accelerates from 0 to 100 mph in less than three seconds. This is more than nine seconds faster than it takes a production Porsche 911 Turbo street car to reach the same speed.
   3. An IndyCar Series car traveling at 220 mph travels slightly more than the length of a football field every second.
   4. An IndyCar Series engine has six pistons. The combined up and down motion equals nearly 1 mile every minute.
   5. Fuel injection is a system-replacing conventional carburetion that delivers fuel under pressure into the combustion chamber of the engine or airflow before entering the chamber.
   6. The 3.5-liter, 100 percent fuel-grade ethanol-powered engines of IndyCar Series cars produce more than 650 horsepower, nearly four times that of the average street car.

2. Divide students into 4-person teams using a teacher preferred method. You may choose to have students count off 1 through 4, repeating until all students have been assigned to one of eight teams. All eight teams will complete the learning activity simultaneously.

   Team 1: 5 lb Kettle bell
   Team 2: 10 lb Kettle bell
   Team 3: Sled
   Team 4: Sled

2:00 – 5:00 minutes

Teacher

1. Demonstrate the activity position.
   a. All team members will have a role:
      i. Driver: Produces horsepower
      ii. Data Technician: Records data
      iii. Data Acquisition Engineer: Operates stopwatch and measuring tape
      iv. Race Engineer: Oversees the operation and performs calculations

2. Demonstrate the stop watch functions: start, stop, and reset.

3. Kettle bells
   a. The driver will lift the kettle bell with two hands on handle. The kettle bell should hang straight down close to waist. Lift straight up, ending close to the chest. So as to avoid shoulder injury, DO NOT allow over-the-shoulder raises.
   b. Measure the vertical distance from bottom to top of kettle bell motion.
   c. One student will perform 10 timed repetitions.
   d. Students must convert inches to feet to calculate horsepower.
   e. Time and distance is used to calculate arm horsepower.

4. Sled
   a. Weight will be pulled 8 feet.
   b. A student will pull the sled by holding the harness-to-step strap over the shoulder as shown below or around the waist depending on which is most comfortable for the student. This is because the harness provided in the kit is too large for most students. Making adjustments for each student will be time consuming.
   c. Time and distance is used to calculate leg horsepower.

5. Announce the information below:
   a. Teams have 2 minutes to complete the task, record data, and compute horsepower.
   b. There will be a 30 second warning to prepare to move.
c. Teams progress to the next highest number position up to #7. The team at position #7 progresses to position #1.
d. Teams will complete each of the three position types at least once.
e. Teams are to progress between positions quickly, like a pit crew.

The sled tension force to use is 11.5 lb based upon the calculation performed during pod set up.

**Position #1**

5:00 – 5:30 minutes

**Teacher**
Guide students to assigned initial position as shown on the pod map.

5:30 – 7:30 minutes

**Students**
Start activity at assigned position.

**Teacher**
Begin timer.

7:30 – 8:00 minutes

**Students**
Calculate power.
Proceed to next position at end of time.

**Teacher**
Call 30 second warning and announce to begin calculations.

**Position #2**

8:00 – 11:00 minutes

**Students**
Complete activity at assigned station.
Calculate power.

**Teacher**
Time for two minutes and call 30 second warning.

**Position #3**

11:00 – 15:00 minutes

**Students**
Complete activity at assigned station.
Calculate power.

**Teacher**
Time for two minutes and call 30 second warning.
Discussion
15:00 – 20:00 minutes
Teacher
Lead reflection on activity.
1. How much horsepower does an IndyCar vehicle produce?
   550 – 700 HP depending on variable turbo used at track.
2. What percentage of an IndyCar racer is your horsepower?
   This will always be very low, e.g. 0.008%.
3. Below are some typical horsepower ratings for common devices.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Average Horsepower Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Toothbrush</td>
<td>0.0094 HP</td>
</tr>
<tr>
<td>Curling Iron</td>
<td>0.13 HP</td>
</tr>
<tr>
<td>EnergyStar Clothes Dryer</td>
<td>0.33 HP</td>
</tr>
<tr>
<td>Vacuum Cleaner</td>
<td>0.93 HP</td>
</tr>
<tr>
<td>Coffee Maker</td>
<td>1.41 HP</td>
</tr>
<tr>
<td>Microwave</td>
<td>1.44 HP</td>
</tr>
<tr>
<td>Electric Stove</td>
<td>1.68 HP</td>
</tr>
<tr>
<td>Honda Accord</td>
<td>185 HP</td>
</tr>
<tr>
<td>Moped</td>
<td>2 HP</td>
</tr>
<tr>
<td>Hair Dryer</td>
<td>2.51 HP</td>
</tr>
<tr>
<td>Electric Oven</td>
<td>2.62 HP</td>
</tr>
<tr>
<td>Chevrolet Malibu</td>
<td>259 HP</td>
</tr>
<tr>
<td>Lawn Mower</td>
<td>5 HP</td>
</tr>
<tr>
<td>IndyCar</td>
<td>650 HP</td>
</tr>
<tr>
<td>Boeing 777-300 GE90-115B</td>
<td>92,000 HP</td>
</tr>
<tr>
<td>Battleship USS Iowa</td>
<td>212,000 shaft HP</td>
</tr>
</tbody>
</table>

4. These are rough approximations of human horsepower.
   a. Sled errors that were ignored: Angle of the pulling strap and kinetic and static friction forces.
   b. Kettlebell errors that were ignored: Force of gravity assistance during the descent and inconsistent motion.
5. Will increasing horsepower automatically increase the speed of the race car?
6. What other factors may increase speed?
7. Should IndyCar choose to increase the horsepower so that the cars can go faster around the raceway?
8. Which produced more horsepower: your legs or arms? Why?
9. Did doubling the weight of the kettle bells have any effect on the horsepower produced?

20:00
Students
Move to next pod.

Professional Development Opportunities
3. Typical horsepower ratings:
   c. [http://www.sizes.com/tools/engines.htm](http://www.sizes.com/tools/engines.htm)
Future of Fast Engine Pod Student Instructions

Introduction

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In this activity your team will determine how much horsepower individuals on a team produce and then calculate the total horsepower of the team. Your team will also compare its total horsepower to INDYCAR engines.

Procedure

1. Proceed to the position assigned to your team.
   - Team 1: 5 lb Kettle bell
   - Team 2: 10 lb Kettle bell
   - Team 3: Sled
   - Team 4: Sled
   - Team 5: Sled
   - Team 6: 10 lb Kettle bell
   - Team 7: 20 lb Kettle bell

2. Organize your team into the four roles described below. As you rotate positions, rotate team roles as well.
   a. Driver: Produces horsepower
   b. Data Technician: Records data
   c. Data Acquisition Engineer: Operates stopwatch and measuring tape
   d. Race Engineer: Oversees the operation and performs calculations

3. Under direction of the teacher, complete the tasks below for each position.
   a. 5 lb, 10 lb, and 20 lb Kettle bell Procedure
      1. The driver will stand up and hold the kettle bell with arm straight down.
      2. The Data Acquisition Engineer will note the position of the kettle bell.
      3. The driver will lift the kettle bell with two hands on handle. Kettle bell should hang straight down close to waist. Lift straight up, ending close to the chest. So as to avoid shoulder injury, DO NOT allow over-the-shoulder raises.
      4. The Data Acquisition Engineer will measure the vertical distance from bottom to top of kettle bell motion and reports it to the Data Technician. The Data Technician will record data on the Student Data Sheet.
      5. The Data Acquisition Engineer will use the stopwatch to time the driver as the kettle bell is raised and lowered 10 times.
      6. The Data Acquisition Engineer will report the time to the Data Technician. The Data Technician will record data on the Student Data Sheet.
      7. The Race Engineer will calculate and record the driver arm horsepower. Make sure to convert inches to feet. If the calculation is not complete before the end of the time allotment, complete calculations at the next position.

   b. Sled Procedure
      1. The Data Acquisition Engineer will confirm the horizontal sled tension force with the data technician.
      2. The driver will prepare to pull the sled 8 feet by holding the harness-to-step strap over the shoulder as shown below or around the waist depending on which is most comfortable for the student.
      3. The Data Acquisition Engineer will use the stopwatch to time the driver pulling the sled from the start to finish line. The Data Acquisition Engineer will report the time to the Data Technician to record on the Student Data Sheet.
      4. The Race Engineer will calculate and record the driver leg horsepower. If the calculation is not complete before the end of the time allotment, complete calculations at the next position.

4. Under direction of the teacher, move to the next highest number position for your team. If your team is at position 7, you will proceed to position 1.
5. Repeat step #3 using your new roles.
6. The Race Engineer will compute and record the total team horsepower on the Student Data Sheet.
Future of Fast Engine Pod Student Data Sheet

Sled Example

| Step 1 | d = displacement 
d = 8 ft |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>$F_p = \text{force parallel to direction of displacement}$</td>
</tr>
<tr>
<td></td>
<td>$F_p = \underline{\text{lb}}$</td>
</tr>
</tbody>
</table>
| Step 3 | t = time 
t = \underline{s} |

Step 4

- $P = \text{power}$
- $W = \text{work}$
- $W = F_p \cdot d$
- $P = \frac{W}{t}$
- $P = \frac{F_p \cdot d}{t}$

Step 5

- $P_H = \frac{\text{lb} \cdot \text{ft}}{\text{s}}$
- $\frac{P_H}{550} = \frac{\text{HP} \cdot \text{s}}{\text{lb} \cdot \text{ft}}$
- $P_H = \underline{\text{HP}}$

Sled Work Area
Kettle Bell Example

**Step 1**
\[ d = \text{displacement} \]
\[ d_{\text{Total}} = \frac{\text{in. Lift} \cdot 10 \text{ Lifts}}{12 \text{ in. ft}} \]
\[ d_{\text{Total}} = \text{_______ ft} \]

**Step 2**
\[ F_{||} = \text{force parallel to direction of displacement} \]
\[ F_{||} = \text{_______ lb} \]

**Step 3**
\[ t = \text{time} \]
\[ t = \text{_______ s} \]

**Step 4**
\[ P = \text{power} \]
\[ W = \text{work} \]
\[ W = F_{||} \cdot d \]
\[ P = \frac{W}{t} \]
\[ P = \frac{F_{||} \cdot d}{t} \]
\[ P = \frac{\text{lb} \cdot \text{ft}}{\text{s}} \]

**Step 5**
\[ P = \text{power} \]
\[ W = \text{work} \]
\[ P_{\text{HP}} = \frac{\text{lb} \cdot \text{ft}}{550 \text{ HP} \cdot \text{s}} \]
\[ P_{\text{HP}} = \text{_______ HP} \]
Future of Fast Fuel Pod: Making Ethanol

Teacher Instructions (Student Instructions at Bottom)

Introduction

Have you seen commercials for E85 and wondered exactly what E85 is? E85 fuel is comprised of 85% denatured ethanol fuel and 15% gasoline.

The process of making ethanol is similar to the fermentation process used to make bread. Fermentation requires two components: bacteria or yeast and an organic nutrient source. The speed of fermentation depends on the ratio of these components and the reaction temperature. When you make bread, yeast converts sugars in the dough to carbon dioxide and alcohol. Air pockets in bread are a result of carbon dioxide bubbles trapped in dough. When the bread is heated in an oven, any remaining alcohol evaporates. The ethanol production processes use yeast, which feed on the sugar found in an organic compound such as corn. In the ethanol biofuel manufacturing process, the ethyl alcohol (ethanol) is collected for use in the E85 fuel blend instead of being allowed to evaporate. An additive is blended with the purified ethanol to make it undrinkable, denatured ethanol.

In this activity students will simulate the fermentation process using yeast, sugar in a soda drink as the organic nutrient source, and a surgical glove to collect the carbon dioxide resulting from the fermentation process.

Equipment

<table>
<thead>
<tr>
<th>Materials Needed for Setup</th>
<th>Materials Needed for Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Liquid-capable trash cans</td>
<td>1. Soda (non-diet) (7 per group)</td>
</tr>
<tr>
<td>2. Cooler</td>
<td>2. Soda (diet) (1 per group)</td>
</tr>
<tr>
<td>3. Water (1 gallon)</td>
<td>3. Yeast (1 teaspoon per team)</td>
</tr>
<tr>
<td>4. Ice</td>
<td>4. Stopwatch (1 per team)</td>
</tr>
<tr>
<td></td>
<td>5. Powder-free non-latex (Nitrile) gloves (1 per team)</td>
</tr>
<tr>
<td></td>
<td>6. Rubber bands (1 per team)</td>
</tr>
</tbody>
</table>
**Procedure for Pod Setup by Teacher**

1. Set up pod according to pod map.

2. Place yeast packet, measuring spoon, glove, and rubber band on tables for each team. Soda will be distributed during the activity.

3. Add ice to cooler and ten regular sodas.

**Procedure for Activity**

**0:00 – 2:30 minutes**

**Teacher**

Guide students to where you prefer to introduce the activity.

Introduce activity using the key points below:

1. Ethanol is a clear, liquid fuel produced by fermentation from crops such as corn, grain sorghum, wheat, sugar, and other agricultural feedstock.
2. Approximately 20 pounds of corn are required to make 1 gallon of ethanol.
3. Ethanol production does not require the importation of expensive crude oil, a non-renewable resource.
4. An IndyCar Series race vehicle uses E85 fuel which is a blend of 85% pure fuel-grade ethanol and 15% gasoline.
5. IndyCar Series race vehicle fuel efficiency is generally less than 2 miles per gallon.
6. The external opening to the fuel cell is called a buckeye.
7. Starting a car with ethanol can be tougher because it does not evaporate as quickly as gasoline, but this is not an issue in racing.
8. When it is used as fuel it burns cooler, making the air denser, which allows it to burn more fuel, thus providing more energy per combustion cycle. It also results in less wear on the engine.
9. Unlike gasoline; ethanol can mix with water, which means when there is a dangerous fire it can be put out with water.
10. IndyCar engines are rebuilt about every 2000 miles. Ethanol burns cleaner than gasoline which extends the life of the pistons and combustion chambers making the rebuild much more effective.
11. Fermentation requires yeast and an organic nutrient source (sugar).
12. The speed of fermentation depends on the ratio of these components and the reaction temperature.
13. The process of making ethanol is similar to the fermenting process used to make bread.
14. During bread making, yeast converts sugars in dough to carbon dioxide and ethanol. Air pockets in bread are a result of carbon dioxide bubbles trapped in the dough. When the bread is heated in an oven, any remaining alcohol evaporates.
15. The ethanol fermentation process uses yeast which feed on the sugars found in an organic compound such as corn.
16. However, in the ethanol biofuel process, the ethyl alcohol (ethanol) is collected and concentrated for use in the E85 fuel blend instead of being allowed to evaporate.
17. Methanol was previously used as a racing fuel in the past. It is made from methane or natural gas, which is a nonrenewable fossil fuel. Fires produced by methanol are more dangerous because it burns clear which makes it hard to know if something is on fire. IndyCars using ethanol also allows technology advances to be more easily advanced to consumer cars since they also use ethanol blends. This link shows Rick Mears on fire due to methanol spill and ignition
https://www.youtube.com/watch?v=NQ_UufZ0eZk

2:30 – 5:00 minutes
Teacher
Remind students that sugar (soda), fungi (yeast), and temperature are the key components in the experiment.
Explain the activity procedure.
1. All stations follow the same procedure.
2. Do not open soda can until after the yeast is measured and ready to be loaded into the can.
3. One student will measure 1 teaspoon of yeast with a measuring spoon.
4. One student will prepare to quickly put the glove over the can and hold the glove so that it does not slip off the can or allow air into the can after the yeast has been added.
5. One student will time how long it takes for the glove to fully inflate.
6. Show how to operate the stopwatch.

Emphasize that students are to move quickly but efficiently, like a pit crew.
Encourage students to be careful adding yeast in the same way that pit crews attach the fuel nozzle to the buckeye of an INDYCAR to avoid wasting or spilling fuel.

5:00 – 7:00 minutes
Teacher
1. Divide students into 4-person teams using a teacher preferred method. You may choose to have students count off 1 through 4, repeating until all students have been assigned to one of eight teams. All eight teams will complete the learning activity simultaneously.
2. The team names and soda or juice needed is shown below.
   - Team 1: Regular soda at room temperature
   - Team 2: Regular soda at room temperature
   - Team 3: Regular soda at room temperature
   - Team 4: Regular soda at room temperature
   - Team 5: Regular soda at room temperature
   - Team 6: Diet soda at room temperature
   - Team 7: Cold soda from iced cooler
   - Team 8: Cold soda from iced cooler

Assistants
Assist movement of students and monitor student behavior.
Replace used soda in cooler with fresh soda.

6:00
Teacher and Assistants
Distribute soda and juice to teams using the list above.

**7:00 – 12:00 minutes**

**Students**
1. Begin fermentation procedure.

**12:00 – 19:00 minutes**

**Students**
Participate in discussion.

**Teacher**
Guide discussion

1. What gas is filling the glove?
   a. Carbon Dioxide. As the yeast eats the sugars it gives off carbon dioxide. Yeast makes bread rise because the carbon dioxide gas bubbles are created and trapped in the bread. Remind them of the giant air pockets in pizza crust.
2. Other liquids like water and ethanol are left in the can. How is the ethanol separated from the water?
   a. Distillation. Ethanol has a lower boiling point than water (~78 degrees Celsius versus 100 degrees Celsius)
      i. Liquid is heated to ethanol’s boiling point
      ii. Ethanol evaporates separating it from water
      iii. Evaporated ethanol is cooled in a condenser back to liquid and collected.

3. Will diet or regular soda inflate the glove more?
   a. Could be either. Many artificial sweeteners also activate yeast. Aspartame is what is used in most diet drinks and may even work better than sucrose or table sugar that is found in regular soda.
4. Will room temperature or cold soda work better?
   a. Warmer liquid better activates the yeast. Too hot can kill the yeast, though, since it is a living organism.
5. Did the beverage can change temperature? Why or why not?
   a. The can should feel warmer. Fermentation gives off heat.

**19:00 – 20:00 minutes**

**Students**
Clean up area and dispose of used material.
20:00

Students

Move to next pod.

Professional Development Opportunities

2. Force of Friction: [http://www.clickandlearn.org/Physics/sph3u/friction_force.htm](http://www.clickandlearn.org/Physics/sph3u/friction_force.htm)
6. Fuel comparisons: [http://www.docbrown.info/page04/OilProducts09.htm](http://www.docbrown.info/page04/OilProducts09.htm)
8. Indy Car Driver Rick Mears Ignited In Flames video: [https://www.youtube.com/watch?v=NQ_UufZ0eZk](https://www.youtube.com/watch?v=NQ_UufZ0eZk)
10. Ethanol production process short videos:
    a. [https://www.youtube.com/watch?v=PVaLN4qpDI8](https://www.youtube.com/watch?v=PVaLN4qpDI8)
    b. [https://www.youtube.com/watch?v=XROVcSC7mds](https://www.youtube.com/watch?v=XROVcSC7mds)
    c. [https://www.youtube.com/watch?v=XnQNWeOZqtQ](https://www.youtube.com/watch?v=XnQNWeOZqtQ)
    d. [https://www.youtube.com/watch?v=VobBk3t6AJ4](https://www.youtube.com/watch?v=VobBk3t6AJ4)
    e. [https://www.youtube.com/watch?v=JWHl4F2M1U](https://www.youtube.com/watch?v=JWHl4F2M1U)
    f. [https://www.youtube.com/watch?v=m1vOMLEdoXk](https://www.youtube.com/watch?v=m1vOMLEdoXk)
    g. [https://www.youtube.com/watch?v=MBKBzdHx-s](https://www.youtube.com/watch?v=MBKBzdHx-s)
Future of Fast Fuel Pod Student Instructions

Introduction

Have you seen commercials for E85 and wonder exactly what E85 is? E85 fuel is comprised of 85% denatured ethanol fuel and 15% gasoline.

The process of making denatured ethanol is similar to the fermenting process used to make bread. Fermentation requires three components: bacteria or fungi, absence of oxygen, and an organic compound. The speed of fermentation depends on the ratio of these components and the reaction temperature. When you make bread, yeast converts sugars in dough to carbon dioxide and alcohol. Air pockets in bread are a result of carbon dioxide bubbles trapped in dough. When the bread is heated in an oven, any alcohol evaporates. The ethanol fermentation process uses bacteria which feeds on sugar found in an organic compound such as corn. However, in the ethanol biofuel process, the ethyl alcohol (ethanol) is collected for use in the E85 fuel blend instead of being allowed to evaporate.

In this activity students will simulate the fermentation process using yeast for bacteria, sugar in a soda drink as the organic compound, and a glove to restrict oxygen.

Procedure

1. Go to your assigned team.
   Team 1: Regular soda at room temperature
   Team 2: Regular soda at room temperature
   Team 3: Regular soda at room temperature
   Team 4: Regular soda at room temperature
   Team 5: Regular soda at room temperature
   Team 6: Regular soda at room temperature
   Team 7: Diet soda at room temperature
   Team 8: Cold soda from iced cooler

1. Leave the can of soda closed.
2. Organize your team into the four roles described below.
   1. Fueler #1: Measures and adds yeast
   2. Fueler #2: Attaches a rubber glove
   3. Fuel Hose Assistant: Secures a glove with an elastic band
   4. Data Acquisition Engineer: Operates the stopwatch
3. Fueler #1 measures 1 teaspoon of yeast and prepares to load it into the can BEFORE opening the can of soda.
4. Data acquisition engineer starts the stopwatch and signals to fueler #1 and #2 to begin.
5. The fuel hose assistant opens the can quickly and steps aside.
6. Fueler #1 adds yeast to the soda.
7. Fueler #2 quickly positions the non-latex glove over the can and holds the glove so that it does not slip off the can or allow air into the can after the yeast has been added.
8. Fuel hose assistant adds an elastic band to the base of the glove.
9. Data acquisition engineer stops the stopwatch when the glove is fully inflated.
10. Data acquisition engineer records the time.
Procedure for Activity

Approximately 30 minutes

1. Teacher introduces activity using the talking points below for guidance.
   1. An IndyCar Series car accelerates from 0 to 100 mph in less than three seconds. This is more than nine seconds faster than it takes a production Porsche 911 Turbo street car to reach the same speed.
   2. An IndyCar Series car traveling at 220 mph travels slightly more than the length of a football field every second.
   3. An IndyCar Series engine has six pistons. The combined up and down motion equals nearly 1 mile every minute.
   4. Fuel injection is a system-replacing conventional carburetion that delivers fuel under pressure into the combustion chamber of the engine or airflow before entering the chamber.
   5. The 3.5-liter, E85 ethanol-powered engines of IndyCar Series cars produce more than 650 horsepower, nearly four times that of the average street car.

2. Teacher divides students into 4-person teams. All teams will complete the learning activity simultaneously.

3. Teacher demonstrates the activity position.
   a. All team members will have a role:
      i. Driver: Produces horsepower
      ii. Data Technician: Records data
      iii. Data Acquisition Engineer: Operates stopwatch and measuring tape
      iv. Race Engineer: Oversees the operation and performs calculations
   b. The stopwatch functions: start, stop, and reset.
   c. Kettle bells.
      i. The driver will lift the kettle bell with two hands on the handle. The kettle bell should hang straight down close to waist. Lift straight up, ending close to the chest. So as to avoid shoulder injury, DO NOT allow them to raise over their shoulders.
      ii. Measure the vertical distance from bottom to top of kettle bell motion.
      iii. One student will perform 10 timed repetitions.
      iv. Students must convert inches to feet to calculate horsepower.
      v. Time and distance is used to calculate “human” horsepower.

4. Announce the information below.
   d. Teams have 2 minutes to complete the task, record data, and compute horsepower.
   e. There will be a 30 second warning to prepare to move.
   f. Teams will rotate.
   g. Teams will complete each of the three position types at least once.
   h. Teams are to progress between positions quickly, like a pit crew.

5. Students complete the activity and calculate power within two minutes.


7. Teacher leads discussion questions.
Discussion Questions

1. How much horsepower does an IndyCar vehicle produce?
   a. 550 – 700 HP depending on variable turbo used at track.
2. Below are some typical horsepower ratings for common devices.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Average Horsepower Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Toothbrush</td>
<td>0.0094 HP</td>
</tr>
<tr>
<td>Curling Iron</td>
<td>0.13 HP</td>
</tr>
<tr>
<td>EnergyStar Clothes Dryer</td>
<td>0.33 HP</td>
</tr>
<tr>
<td>Vacuum Cleaner</td>
<td>0.93 HP</td>
</tr>
<tr>
<td>Coffee Maker</td>
<td>1.41 HP</td>
</tr>
<tr>
<td>Microwave</td>
<td>1.44 HP</td>
</tr>
<tr>
<td>Electric Stove</td>
<td>1.68 HP</td>
</tr>
<tr>
<td>Honda Accord</td>
<td>185 HP</td>
</tr>
<tr>
<td>Moped</td>
<td>2 HP</td>
</tr>
<tr>
<td>Hair Dryer</td>
<td>2.51 HP</td>
</tr>
<tr>
<td>Electric Oven</td>
<td>2.62 HP</td>
</tr>
<tr>
<td>Chevrolet Malibu</td>
<td>259 HP</td>
</tr>
<tr>
<td>Lawn Mower</td>
<td>5 HP</td>
</tr>
<tr>
<td>IndyCar</td>
<td>650 HP</td>
</tr>
<tr>
<td>Boeing 777-300 GE90-115B</td>
<td>92,000 HP</td>
</tr>
<tr>
<td>Battleship USS Iowa</td>
<td>212,000 shaft HP</td>
</tr>
</tbody>
</table>

3. These are rough approximations of human horsepower because errors were ignored. What are some examples of errors which were ignored?
   a. Force of gravity assistance during the descent and inconsistent motion.
4. Will increasing horsepower automatically increase the speed of the race car?
   a. In general yes, but not always because given the grip as well as aero and track configuration and conditions, all horsepower may not be able to be utilized.
5. Should IndyCar choose to increase the horsepower so that the cars can go faster around the raceway?
   a. Teams and engine manufacturers are consistently trying to gain horsepower given the rules for engines. In fact, with two manufacturers it is common for one to have more horsepower, but the tradeoff is less fuel economy. Student answers will vary, but while adding horsepower could be accomplished through different rules, safety must be carefully considered along with increased costs for teams.
6. Did doubling the weight of the kettle bells have any effect on the horsepower produced?
   a. Theoretically the horsepower should be the same, but it is also possible that if the lighter kettle bell is too easy to lift, the individual might spend unnecessary time slowing it down. Conversely the heavier kettle bell might be so heavy that it is hard to lift, especially toward the end of the cycle. A weight likely exists that would be optimal for producing the most “human” horsepower.
7. What percent of an IndyCar engine of did you represent?
   a. This will always be very low, e.g. 0.008%.

Next Generation Science Standards Connections

Disciplinary Core Idea
MS-PS2.A Forces and Motion: The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

Crosscutting Statements (Grades 6-8)
Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
Stability and Change: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Science and Engineering Practice (Grades 6-8)
Using Mathematics and Computational Thinking: Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.
Future of Fast Engine Pod Student Instructions

Introduction

Have you heard a car commercial claim that a vehicle has 185 horsepower and wondered what that means? How is horsepower determined? How is a car related to horses? The Scottish engineer and inventor James Watt is credited with crafting the term “horsepower” in the 18th century. He wanted a unit of measurement that could compare the power of a steam engine to a horse. Mr. Watt calculated that one of his ponies could generate 22,000 foot-pounds of work in a minute while lifting coal from a mine. He increased the calculation by 50%, thus establishing 33,000 foot-pounds of work per minute as the unit we call horsepower.

In this activity your team will determine how much horsepower individuals on a team produce and then calculate the total horsepower of the team. Your team will also compare its total horsepower to INDYCAR engines.

Procedure

8. Proceed to the position assigned to your team.
9. Organize your team into the four roles described below. As you rotate positions, rotate team roles as well.
   a. Driver: Produces horsepower
   b. Data Technician: Records data
   c. Data Acquisition Engineer: Operates stopwatch and measuring tape
   d. Race Engineer: Oversees the operation and performs calculations
10. Under direction of the teacher, complete the tasks below for each position.
    a. The Driver will stand up and hold the kettle bell with arm straight down.
    b. The Data Acquisition Engineer will note the position of the kettle bell.
    c. The driver will lift the kettle bell with two hands on handle. Kettle bell should hang straight down close to waist. Lift straight up, ending close to the chest. So as to avoid shoulder injury, DO NOT lift over-the-shoulder.
    d. The Data Acquisition Engineer will measure the vertical distance from bottom to top of kettle bell motion and report it to the Data Technician. The Data Technician will record data on the Student Data Sheet.
    e. The Data Acquisition Engineer will use the stopwatch to time the driver as the kettle bell is raised and lowered 10 times.
    f. The Data Acquisition Engineer will report the time to the Data Technician. The Data Technician will record data on the Student Data Sheet.
    g. The Race Engineer will calculate and record the driver arm horsepower. Make sure to convert inches to feet. If the calculation is not complete before the end of the time allotment, complete calculations at the next position.
11. Rotate to the next station.
12. Repeat step #3 using your new roles.
13. The Race Engineer will compute and record the total team horsepower on the Student Data Sheet.
Future of Fast Engine Pod Student Data Sheet

Kettle Bell Example

Step 1
\( d = \text{displacement} \)
\[ d_{\text{Total}} = \frac{\text{Lift \cdot 10 Lifts}}{12 \text{ in.}} \]
\( d_{\text{Total}} = \underline{\text{ft}} \)

Step 2
\( F_{||} = \text{force parallel to direction of displacement} \)
\( F_{||} = \underline{\text{lb}} \)

Step 3
\( t = \text{time} \)
\( t = \underline{\text{s}} \)

Step 4
\( P = \text{power} \)
\( W = \text{work} \)
\[ W = F_{||} \cdot d \]
\[ P = \frac{W}{t} \]
\[ P = \frac{F_{||} \cdot d}{t} \]

Step 5
\( P = \text{power} \)
\( W = \text{work} \)
\[ P_{\text{HP}} = \frac{550 \text{ lb \cdot ft}}{\text{HP \cdot s}} \]
\[ P_{\text{HP}} = \underline{\text{HP}} \]

Kettle Bell Work Area
Future of Fast Safety Pod: SAFER Barrier

Teacher Instructions (Student Instructions at Bottom)

Introduction

IndyCar Series drivers endure incredible forces during a race. A crash subjects a driver to forces that can cause injury and even death, so safety systems are used to reduce forces on drivers. One example is the development by INDYCAR of the SAFER Barrier (Steel and Foam Energy Reduction) which absorbs energy during a crash. The barrier is constructed of steel tubes and bundles of polystyrene between the concrete wall and the steel tubing modules. More information is available at https://en.wikipedia.org/wiki/SAFER_barrier

In this activity students will design, build, and test a SAFER Barrier using simple construction supplies.

Equipment

<table>
<thead>
<tr>
<th>Materials Needed for Setup</th>
<th>Materials Needed for Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SAFER Barrier</td>
<td>1. Plastic container for supplies (1 / team)</td>
</tr>
<tr>
<td>2. LabQuest 2 (2 + 1 backup)</td>
<td>2. 3 x 5 in. colored index cards (8 / team)</td>
</tr>
<tr>
<td>3. LabQuest 2 AC chargers (2 + 1 backup)</td>
<td>3. Scissors (2 / team)</td>
</tr>
<tr>
<td>4. Vernier 25-g accelerometer (2 + 1 backup)</td>
<td>4. Ruler (1 / team)</td>
</tr>
<tr>
<td>5. VEX vehicle (2 + 1 backup)</td>
<td>5. Letter size paper (10 / team)</td>
</tr>
<tr>
<td>6. 3D Printed adapter to mount 25-G sensor to vehicle (2 + 1 backup)</td>
<td>6. Tacky glue (4 oz) (1 bottle / team)</td>
</tr>
<tr>
<td>7. Ramp (2 + 1 backup)</td>
<td>7. Tape dispenser (1 / team)</td>
</tr>
<tr>
<td>8. TV with WiFi (1)</td>
<td>8. Drinking straws (flexible) (4 / team)</td>
</tr>
<tr>
<td>9. Computer to display multimedia on WiFi TV (1).</td>
<td>9. Pool noodle (4 in. of noodle / team)</td>
</tr>
<tr>
<td>10. LabQuest display software loaded on computer</td>
<td>10. Pen (1 / student)</td>
</tr>
<tr>
<td>11. SAFER Barrier poster (if available)</td>
<td>11. Sharpie markers (2 / team)</td>
</tr>
<tr>
<td>12. Poster of timeline (if available)</td>
<td></td>
</tr>
<tr>
<td>13. Stop watch (1)</td>
<td></td>
</tr>
<tr>
<td>14. White board (1)</td>
<td></td>
</tr>
<tr>
<td>15. Dry erase marker (1 + 5 backup)</td>
<td></td>
</tr>
<tr>
<td>16. Dry eraser or rag (1 + 1 backup)</td>
<td></td>
</tr>
</tbody>
</table>
Procedure for Pod Setup by Teacher

1. Set up pod according to pod map.

2. If not already installed, then add material label to the side of container for more efficient restocking.
3. Fill containers with supplies for eight teams following the materials list above.
4. Set up the dry erase board similar to the example shown below.

<table>
<thead>
<tr>
<th>Team</th>
<th>Maximum Deceleration</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Josef Newgarden</td>
<td>115.5</td>
<td></td>
</tr>
<tr>
<td>Marco Andretti</td>
<td>102.6</td>
<td></td>
</tr>
<tr>
<td>Graham Rahal</td>
<td>152.2</td>
<td></td>
</tr>
<tr>
<td>James Hinchcliffe</td>
<td>96.3</td>
<td></td>
</tr>
<tr>
<td>Simona de Silvestro</td>
<td>158.8</td>
<td></td>
</tr>
<tr>
<td>Tony Kanaan</td>
<td>133.9</td>
<td></td>
</tr>
<tr>
<td>Will Power</td>
<td>112.5</td>
<td></td>
</tr>
<tr>
<td>Charlie Kimball</td>
<td>99.3</td>
<td></td>
</tr>
</tbody>
</table>

5. Power on all of the LabQuest2 units and confirm that all are fully charged.
6. Set up LabQuest Display to WiFi TV.
   a. Initialize LabQuest WiFi connection on LabQuest. Select the Home icon at the bottom of the screen. Select Connections, then select WiFi On.
   b. Start LabQuest Viewer software on computer and display on WiFi TV.
   c. Select LabQuest2 to display.
   e. This activity requires a lot of battery energy, so recharge the LabQuest2 minimally in between sessions.

**Procedure for Activity**

**0:00 – 2:30 minutes**

**Students**
Enter and form group around front near SAFER barrier.

**Teacher**
1. Guide students to where you prefer to introduce the activity. In front near the SAFER barrier works well.
2. Introduce activity using the points below.
   1. What is a g-force?
      - An acceleration or deceleration measured in multiples of the Earth's gravitational force.
   2. How much is the Earth's gravitational force?
      - 32 ft/s² or 9.8 m/s²
3. How much gravity is acting on all of you sitting down? 
   1-g, 32 ft/s² or 9.8 m/s²
4. If you were to fall onto the ground would you be exposed to more than 1-g force? 
   Yes, because deceleration would occur when you hit the ground.
5. The human body cannot tolerate high g-forces without injury or death.
6. During a crash, g-forces (decelerations) are high.
7. Reducing g-forces (deceleration) improves survival.
8. What does a car look like after an accident and why does it look like that? 
   The crumpled car absorbs the forces of a crash and reduces g-forces (decelerations).
9. SAFER Barriers were designed by IndyCar to provide crash zone protection against the wall of the track 
    during a crash. Refer to the IndyCar Media Guide SAFER Barrier page within this document for 
    background knowledge.
10. Allow students to examine the actual SAFER Barrier.
11. Optional: Show 60 second IndyCar 101 (SAFER Barrier)  
    http://www.youtube.com/watch?v=K384mhBfMC8
3. Announce general information below: 
   1. Timeline is approximately 15 minutes to design and test. 
   2. Encourage multiple tests of SAFER Barriers as part of develop, construct, test, evaluate, and repeat. 
   3. Use the paper provided for barrier construction AND sketching. 
   4. Warn that the 2 in. thick constraint may require the material between the index cards to be less than 2 in. 
   5. Tacky glue sets quickly, although tape can also be used.
4. Demonstrate impact with vehicle to display G-force without SAFER Barrier. 
5. Announce the deceleration value of the car striking wood (this is the worst-case scenario that students need 
   to improve).
6. Report value to the assistant to record at top of the Leader Board.

Assistants 
   Record values on the leader board.

2:30 – 3:00 minutes 
Teacher 
   1. Divide students into 4-person teams using a teacher preferred method. You may choose to have students 
      count off 1 through 4, repeating until all students have been assigned to one of eight teams. All eight teams 
      will complete the learning activity simultaneously.
   2. Assign student teams to one of the team names listed below. 
      1. Josef Newgarden 
      2. Marco Andretti 
      3. Graham Rahal 
      4. James Hinchcliffe 
      5. Simona de Silvestro 
      6. Tony Kanaan 
      7. Will Power 
      8. Charlie Kimball

3:00 – 3:30 minutes 
Teacher 
   Distribute materials in bins with the help of the assistants.

Assistants 
   Assist with distribution of material.

3:30 – 17:00 minutes 
Students 
   Design and build SAFER Barrier(s) using the constraints below: 
   1. SAFER Barrier must have one 3 x 5 in. index card front and rear side. 
   2. Maximum dimensions = 3 in. wide x 5 in. height x 2 in. thick 
   3. Use the materials provided.

Teacher 
   1. Operate the Vernier LabQuest2 using the procedure below to test the SAFER barrier constructions. Display 
      LabQuest2 on WiFi TV.
   2. Alternate between two ramps. One ramp is used for student set up while the other ramp is active.

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3. Encourage multiple tests.

Notes related to the materials:
1. Effective SAFER Barriers are constructed to collapse, not to cause the vehicle to bounce.
2. The pool noodle is simple to use as a barrier material, but it does not significantly decrease deceleration because the vehicle bounces. This is a good student distractor that allows a student to experience success with improved barrier performance and a great teachable opportunity for students to recognize that the material is elastic.
3. Straws oriented along the direction of impact do not significantly decrease deceleration because they often do not collapse.
4. A simple and effective barrier is made of paper folded like an accordion and glued between the index cards.

Example SAFER Barriers

Assistants
1. Update the Leader Board.
2. Restock second set of eight containers with new supplies for upcoming student teams.

17:00 - 19:00 minutes

Students
Participate in discussion.

Teacher
Announce best SAFER Barrier.
Guide discussion on results.
1. What makes a poor SAFER Barrier?
   SAFER barriers that do not collapse during an impact, including the pool noodle and straws, are not particularly effective.
2. What makes an effective SAFER Barrier?
   SAFER barriers that collapse during impact, such as folded paper.

19:00 – 20:00 minutes

Students
Return supplies to containers.
Keep or throw out SAFER Barrier constructions.

20:00

Students
Move to next pod.
Vernier Sensor Procedure

1. Place the test vehicle in the T-channel so the front of the wheels rest against the channel until ready to release.

2. Plug the accelerometer cable into the CH1 on the left side of the unit.

3. Power on the LabQuest 2 by pushing the red On button at the top of the unit. Confirm that all devices are fully charged. Use either your finger or the stylus located at the back right corner of the unit to use the touch screen.
4. Touch File, and then select New.
5. Touch Sensors, and then select Data Collection.
   a. Touch Rate and enter 5000 sample/s.
   b. Touch Done.
   c. Touch Duration, enter 1.0 s, and then touch Done.
   d. Touch Enable Trigger, and then touch Enable check box.
   e. Scroll down by touching bar on right.
   f. Touch Decreasing and change Crossing to 10 m/s².
   g. Change Collect Points Before Trigger to 1000. Note that the summary screen below only displays 3 digits.
   h. Touch OK.

6. Students place SAFER Barrier VERTICALLY at end of ramp centered between L-brackets.

7. Place the vehicle on the ramp with the back of the wheels touching the T-channel while holding it in place with the string, NOT the black sensor cable.
8. Touch the Ch1: Acceleration display on the screen. Then touch zero. The display should now read close to or exactly \(0 \text{ m/s}^2\).

9. Touch the Graph icon to display a graph to record. Touch the green arrow on the bottom left to start recording. Note that the graph will not begin to display until the vehicle strikes the end of the ramp.

10. Release vehicle while guiding the string and sensor cable to allow vehicle to coast without resistance.
11. Swipe finger or use included stylus left to right over acceleration spike. Touch Analyze, Statistics, then Acceleration.

12. Read the maximum NEGATIVE acceleration to team and the assistant updating the Leader Board. The example below shows a -60.5 m/s² value.

13. Students will write the acceleration value and units on the crushed SAFER Barrier and then remove the barrier.

Professional Development Opportunities
2. INDYCAR 101: SAFER Barrier video: [http://www.youtube.com/watch?v=K384mhBfMC8](http://www.youtube.com/watch?v=K384mhBfMC8)
6. SAFER Barrier media guide shown below.
SAFER BARRIER

On May 1, 2002, INDYCAR founder Tony George announced a safety innovation that revolutionized the sport of automobile racing. George announced that the SAFER (Steel and Foam Energy Reduction) Barrier would be installed in all four turns of the Indianapolis Motor Speedway in time for practice for that year’s Indianapolis 500 Mile Race.

Under development by the league and the University of Nebraska-Lincoln’s Midwest Roadside Safety Facility since 1998, the SAFER Barrier was designed to reduce the severity of impacts by IZOD IndyCar Series cars, one of the most-effective safety measures taken in the racing industry in recent years.

The SAFER Barrier is constructed in 20-foot modules, with each module consisting of four rectangular steel tubes, welded together, to form a unified element. The modules are connected with four internal steel splices. Bundles of 2-inch-thick sheets of extruded, closed-cell polystyrene are placed between the concrete wall and the steel tubing modules.

Version 2 of the SAFER system was developed during 2002 and 2003 by the same team that developed the original SAFER system in response to many detailed studies of the original SAFER. Version 2 incorporates improvements that further minimize damage to the system upon impact, allow one configuration to be used for both open-wheel and stock cars and allow SAFER Barriers to be installed on virtually any racetrack geometry, regardless of corner radius or banking. Since late 2003, Version 2 has become the standard and has been installed on a majority of the racetracks hosting open-wheel and stock-car racing.

All five ovals on the 2012 IZOD IndyCar Series schedule have the system installed in all four turns. Iowa Speedway has installed the Alternative Backup Structure for the SAFER Barrier into its track design. On other tracks the system has been “retro-fitted” to the existing concrete walls (mainly in the turns) of racetracks. Iowa Speedway is the first track to have the SAFER Barrier system around the entire perimeter of the track. It’s also the first to install the new system, which does not have a concrete wall behind it.

Under the direction of George, other key IMS and INDYCAR officials involved in the development of the SAFER Barrier include IMS Director of Engineering and Construction Kevin Forbes, retired INDYCAR Senior Technical Director Phil Casey, INDYCAR President of Operations and Strategy Brian Barnhart and former INDYCAR Director of Medical Services Dr. Henry Bock. The team has worked closely with Dr. Dean Sicking, director of the Midwest Roadside Safety Facility, and his staff since 1998.

AWARDS AND RECOGNITION

Since its introduction, the SAFER Barrier has earned four major accolades:
- Autosport Pioneering and Innovation Award (2004)
- Louis Schwitzer Award (2002)
- SEMA Motorsports Engineering Award (2002)
- GM Racing Pioneer Award (2002)
Introduction

IndyCar Series drivers endure incredible forces during a race. A crash subjects a driver to forces that can cause injury and even death, so safety systems are used to reduce forces on drivers. One example is the development by INDYCAR of the SAFER Barrier (Steel and Foam Energy Reduction) which absorbs energy during a crash. The barrier is constructed of steel tubes and bundles of polystyrene between the concrete wall and the steel tubing modules.

Materials

1. Plastic container for supplies
2. 3 x 5 in. colored index cards (8 / team)
3. Scissors (2 / team)
4. Ruler (1 / team)
5. Letter size paper (10 / team)
6. Tacky glue (4 oz) (1 bottle / team)
7. Tape dispenser (1 / team)
8. Drinking straws (flexible) (4 / team)
9. Sharpie markers (2 / team)
10. Pool noodle (4 in. of noodle / team)
11. Activity instructions (1 / student)
12. Pen (1 / student)

Your Task

IndyCar drivers are depending on you! Design, build, and test a SAFER Barrier to reduce the deceleration to the lowest possible level using the constraints below. You can test the SAFER Barrier as reasonably often as you need to, though you must return to the end of the line after each test. You can use the scale on the back of this page in place of a ruler. You can use the Ideas area to make any sketches and record data. Use the paper provided for barrier instruction and sketching. If you need to view or make measurements of the test vehicle, ask the facilitator.

Constraints:

1. SAFER Barrier must have one 3 x 5 in. index card front and rear side.
2. Maximum dimensions = 3 in. wide x 5 in. height x 2 in. thick
3. Use the materials provided.
<table>
<thead>
<tr>
<th>Run #1 Deceleration</th>
<th>Run #2 Deceleration</th>
<th>Run #3 Deceleration</th>
<th>Run #4 Deceleration</th>
</tr>
</thead>
</table>

**Ideas**

**Inch Scale**

0 1 2 3 4 5 6
**Future of Fast Tire Pod: Grip**

**Teacher Instructions (Student Instructions at Bottom)**

**Introduction**

According to IndyCar driver Ryan Hunter-Reay, “as a racing driver, you love two things—grip and horsepower.” What does he mean by grip?

Grip refers to a tire’s ability to stick to or “grip” a track. There are two types of grip: aerodynamic and mechanical. Grip is increased aerodynamically by controlling the air flow around, over, and under the car to create down force, which increases grip. Mechanical grip is increased by changes to the suspension, steering, tire camber, and tire material.

In this activity students will compare the grip of various materials against a friction board.

**Equipment**

<table>
<thead>
<tr>
<th>Materials Needed For Setup</th>
<th>Materials Needed For Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. TV with WiFi (1)</td>
<td>1. LabQuest2 (8) Note: Use LabQuest2 calculator function</td>
</tr>
<tr>
<td>2. Computer to display multimedia on WiFi TV (1)</td>
<td>2. Dual Range Force Sensor (8)</td>
</tr>
<tr>
<td>3. LabQuest Display software loaded on computer</td>
<td>3. Friction board (8)</td>
</tr>
<tr>
<td>4. Teacher demonstration</td>
<td>4. Block with two hooks (8)</td>
</tr>
<tr>
<td>a. LabQuest2 (1)</td>
<td>5. Stack of nuts to add weight to friction block (8)</td>
</tr>
<tr>
<td>b. Dual Range Force Sensor (1)</td>
<td>6. Paper clip (8)</td>
</tr>
<tr>
<td>c. Friction board (1)</td>
<td>7. Pen (16)</td>
</tr>
<tr>
<td>d. Block with two hooks (1)</td>
<td>8. Future of Fast Tire Pod: Student Data Sheet (1 for each team expected)</td>
</tr>
<tr>
<td>e. Stack of nuts to add weight to friction block (8)</td>
<td></td>
</tr>
<tr>
<td>f. Paper clip (1)</td>
<td></td>
</tr>
</tbody>
</table>

| 8. Future of Fast Tire Pod: Student Data Sheet (1 for each team expected) | 8. Future of Fast Tire Pod: Student Data Sheet (1 for each team expected) |

Project Lead The Way, Inc. and IndyCar ● Copyright 2013 ● Future Of Fast Tire Pod: Grip
Procedure for Pod Setup by Teacher

1. Set up pod according to pod map.

2. Place the materials shown on the list above for each team. Two teams share each table.

3. Power on the LabQuest 2 by pushing the red On button at the top of the unit. Confirm that all devices are fully charged. Use either your finger or the stylus located at the back right corner of the unit to use the touch screen.

4. Connect LabQuest display to WiFi TV
   a. Initialize LabQuest WiFi connection on LabQuest2. Select the Home icon at the bottom of the screen. Select Connections, and then select WiFi On.
   b. Start LabQuest Viewer software on computer and display on WiFi TV.
   c. Select LabQuest2 to display.
5. Unfold the paper clip and connect it to the hook on the Dual Range Force Sensor.
6. Turn one paperclip hook so that it is 90 degrees relative to the other hook.
7. Remove thumb knob on dual range force and replace it with the long metal rod utility handle.
8. Plug the Dual Range Force Sensor cable into the CH1 on the left side of the unit.
9. Test LabQuest2:
   a. Set the range switch on the face of the Dual Range Force Sensor to +/- 10 N.
   b. Touch Duration on right side of screen to confirm that the default settings are as shown below:
      1. Set the sample rate to be 50 samples/s. The interval will automatically update to 0.02 seconds.
      2. Change Duration of time to 10 seconds.
      3. Select OK.
10. Instruct Assistants on the use of the LabQuest2 so that they can assist student teams during the activity.
11. If you will display the LabQuest2 screen on the TV, access the saved TireGripDemo file (or create and save a “good” example of the friction force data and graph).

Professional Development
1. You may wish to review the following videos to prepare for the activity.
   1. This 60 second INDYCAR 101: Rain Tires video provides information for your own professional development: http://www.youtube.com/watch?v=U8B9YrxJTSk
   2. This tire safety site provides information for your own professional development: http://www.tiresafety.com/

Procedure for Activity
0:00 – 4:00 minutes
Teacher
1. Divide students into 4-person teams using a teacher preferred method. You may choose to have students count off 1 through 4, repeating until all students have been assigned to one of eight teams. All eight teams will complete the learning activity simultaneously.
2. Guide students to their assigned positions. All positions will perform similar tasks.
3. Introduce activity using the questions below for guidance.
   1. What makes a race car “go”? Based on their experience and which pod activities they have already completed, the answers will vary. Examples are shown below:
      a. Gas or fuel to power the engine
      b. Engine or power to turn the axle(s)
      c. TIRES to create a force on the pavement to propel the car. If the car tires are not in contact with the pavement (e.g., the car is suspended and will not move. The tires will simply spin.)
2. What makes a race car stop?
   a. Brakes to stop the tires from turning.
   b. Tires because when tires are not allowed to turn, the rubber “skids” across the pavement. Again, there is a force exerted between the tires and the pavement, but in this case the force causes the car to slow down and stop.

3. What is name of the force between the tires and the pavement?
   Friction

General Background Information:
1. IndyCar Series teams select tires based on many factors.
2. Teams choose between primary, alternate, and rain tires based on track conditions and race strategy.
3. Teams are given only a limited number of sets of tires. For instance, at the Houston race, teams are allowed 9 sets of primary tires and 3 sets of alternate tires to use for the entire week including 1 practice, 2 qualification runs, and 2 races. Teams strategically plan which tires they will use for practice/qualifying and how many of each type of tire to reserve for the race. If available update this information for your race event.
4. Tires available to teams:
   a. Primary (black-sidewall) dry-condition slicks
      i. Typical race tire with longest wear life.
      ii. More dense rubber than alternate tires.
   b. Alternate (red-sidewall) dry-condition slicks
      i. Positive: Compound will provide more grip and will adhere to the track surface better, leading to better braking and faster cornering speeds.
      ii. Negative: Tires wear faster.
   c. Wet-condition (rain) tires with grooved tread pattern.
5. Avoid confusing students by implying that the contact area affects frictional force. Only the weight and contact materials affect the frictional force. Avoid talking about the fact that at any given time, the four tires used on an IndyCar have a combined ground contact area similar in size to an 8 ½ in. x 11 in. sheet of paper.
6. This 60 second INDYCAR 101: Rain Tires video provides information for your own professional development: [http://www.youtube.com/watch?v=U8B9YrxJTSk](http://www.youtube.com/watch?v=U8B9YrxJTSk)
7. This tire safety site provides information for your own professional development: [http://www.tiresafety.com/](http://www.tiresafety.com/)

4:00 – 15:00 minutes
Teacher
1. Tell students that in this activity, they will investigate frictional force and compare the frictional force required to move an object across different materials: rubber, sandpaper, cork, and melamine.
2. Ask students not to touch the equipment as you demonstrate the procedure.
3. Describe the equipment.
   a. LabQuest2
      i. Recording data
      ii. Use as a calculator
   b. Dual range force sensor
   c. Friction board
4. Demonstrate a trial run. Show the resulting graph of the friction force on the TV.
5. If your trial run did not result in “good” data, display the saved TireGripDemo file graph.
6. Explain the graph axes:
   a. Force is measured in Newtons (SI units)
   b. Horizontal axis measures time in seconds
7. Ask students to explain what causes changes in the displayed graph (started pulling, block started moving, block was moving at a steady pace, stopped pulling and the block stopped moving, etc.).
8. Ask students:
   a. Does it take more force to get the block moving or to “keep” it moving? How can you tell?
   It takes more force to get the block moving. You can tell by the “spike” in the graph, which indicates that the force necessary to get the block moving is greater.
   b. Why isn’t the frictional force zero after the block stops moving?
   A small tensile force remains in the paper clip after you stop pulling, but it is not enough to overcome the friction.

9. Have students adopt team roles within each group:
   a. Material Technician: Pulls the block across a material.
   b. Data Technician: Records data and performs calculations.
   c. Equipment/Race Engineer: Sets up equipment and oversee the operation. Responsible for verifying recorded data and checking calculations.
   d. Data Acquisition Engineer: Operates the LabQuest2 unit.

10. Have Equipment/Race Engineer set up equipment as you demonstrate.

11. Have Material technician practice pulling block across friction board with slow, even force.

12. Ask students to predict which material they believe will require the greatest frictional force to move the block and which material they believe will require the least frictional force to move the block. Ask each group to indicate their predictions on their data sheet.

13. Have students run a second trial run (choose one material and have all teams practice with that material) as the Data Acquisition Engineer records data using LabQuest2.

14. Demonstrate on TV display how to estimate the mean of the kinetic frictional force during the trial.

15. Have Data Acquisition Engineer and Equipment/Race Engineer estimate the mean of the kinetic force.

16. Ask Data Technician to share the mean kinetic friction for their group. The mean kinetic friction force value should be fairly consistent among the groups. If not, ask Assistants to assist groups that are obtaining erroneous data.

17. Emphasize that students are to move quickly, as though they are a pit crew with major repairs to complete.

18. Announce that students have approximately 9 minutes to complete and record data.

15:00 – 19:00 minutes

Teacher

1. Ask Data Technician from each group that tested rubber to share the group’s average kinetic friction force. If the two groups have obtained similar data, choose one value or approximate an average of the two and have all groups record this value in the last column for rubber on their data recording sheet.

2. Repeat for each material tested: sandpaper, melamine, and cork.

3. Guide a discussion about the activity. Below are suggestions.
   a. Which material required the greatest frictional force to move the block?
   b. Which material required the smallest frictional force to move the block?
   c. Why was this the case? What material characteristic influences the frictional force required to move the block?
   Texture of the surface, softness (spongy-ness) of the surface.
   d. Would you expect to record the same friction force if the wooden block was painted? If the bottom of the wooden block was covered with a layer of glass? Why or why not?
In fact, the friction force required to move the block depends on the material of the bottom surface as well as the material of the block. The rougher the surface of the block, the greater the friction force required to move the block on any surface.

e. What other factors might increase the frictional force required to move the block? If time allows, encourage students to test their hypothesis.

Adding weight(s) to the block would increase the frictional force. In fact, the friction force is directly proportional to the weight of the object being pulled across the surface. So, twice as much weight would require twice as much frictional force to move the block.

f. For students who have completed the air foil activity, how does the airfoil affect frictional force between the tire and the pavement?

g. How would an increased weight (say a full tank of gas) or increased downward force affect the stopping distance of a race car when the brakes are applied?

h. How does friction affect tire material choices for an IndyCar team?

Answer: Track conditions, air temperature, and race strategy

i. What are examples of when friction can be considered “good”?

Answer: Steering wheel so you can hold on to the steering wheel, anti-lock brakes, gym shoes for playing sports, etc.

j. What are examples of when friction can be considered “bad”?

Answer: Engine parts such as pistons, bearings on skateboards and roller blades, etc.

k. If students completed the Collect Alternate Configuration Friction Data section: Based on your knowledge of surface area and the frictional force, should IndyCar increase or decrease the surface area of tire that remains in contact with the road surface of the track? Why?

19:00 – 20:00 minutes

Teacher

Make announcements:

1. End of activity
2. Clean up
3. Engineer keeps completed Student Data Sheet

20:00 minutes

Students

Move to next pod.

Professional Development Opportunities

1. Brembo Brakes on the new DW12 INDYCAR Video - https://www.youtube.com/watch?v=0qH4s4f2yYw
5. IndyCar 101 Rain Tires - http://www.youtube.com/watch?v=U8B9YrxFTSk
7. Click and Learn Physics - http://www.clickandlearn.org/Physics/sph3u/friction_force.htm
12. Vernier resources related to friction -
Future of Fast Tire Pod Student Instructions

Introduction

According to IndyCar driver Ryan Hunter-Reay, "as a racing driver, you love two things – grip and horsepower." What does he mean by grip?

Grip refers to a tire’s ability to stick to or “grip” a track. There are two types of grip: aerodynamic and mechanical. Grip is increased aerodynamically by controlling the air flow around, over, and under the car to create down force, which increases grip. Mechanical grip is increased by changes to the suspension, steering, tire camber, and tire material.

In this activity you will compare the grip of various materials against a friction board.

Setup up Equipment

1. Organize your team into these four roles:
   a. Material Technician: Pulls the block across a material.
   b. Data Technician: Records data.
   c. Race Engineer: Oversee the operation and performs calculations.
   d. Data Acquisition Engineer: Operates the LabQuest2 unit.
2. Material technician prepare materials to test:
   a. Lay the testing material and Dual Range Force Sensor on the table as shown.
   b. Move the force sensor so that the paper clip hangs “loosely” between the Dual Range Force Sensor and material being tested.
   c. Confirm that there still is no tension in the paper clip and the Dual Range Force Sensor.
3. Data Acquisition Engineer prepares the LabQuest2
   a. Click Sensors on the menu bar, and then select Zero to set the Dual Range Force Sensor to zero in the current orientation.
   b. Click the CH 1: Dual Range Force 10N.

**Practice**

4. Material technician will practice pulling the handle of the Dual Range Force Sensor at a steady speed. HINT – if you can pull it from front to back in about 3 seconds that is a useful benchmark.
   a. Dual Range Force Sensor handle must be held horizontally relative to the table while pulling so that the sensor does not pull up or down on the material.

5. Data Acquisition Engineer will verify that test run data is valid:
   a. Click the “green arrow” in the lower left of the screen to start a new test.
   b. Data will stop recording after 10 seconds or when the “red block” in the lower left of the screen is clicked.
   c. The data collected as you pull is shown in graphical form. Note where you began pulling the testing material.

**Collect Friction Data**

6. Your team will test all four materials. Predict which of the surfaces will require the most force to overcome friction to move the block. The data technician will place a star next to that material on your data sheet.
7. The Material Technician will place the block on the runner section of the friction sheet large side down.
8. The Instrument Technician will start a new test run by clicking the green arrow on the bottom left of the screen.
9. The Material Technician will pull the block using the handle of the Dual Range Force Sensor.
10. The data Acquisition Engineer will observe that a portion of the graph just after the large spike should appear higher and be relatively flat and parallel to the “0” (Zero) X-axis of the graph. Touch the beginning of this portion of the graph immediately right of the spike and drag to the right. This will highlight this portion of the data so that it may be analyzed as shown below.
13. The Data Acquisition Engineer will estimate the average force for this portion of the graph.
14. OPTIONAL: The Data Acquisition Engineer will highlight the level area at the top and chose \( \rightarrow \) Analyze on the menu bar, then select \( \rightarrow \) Statistics and the \( \rightarrow \) Force to see the mean average.

15. Data Acquisition Engineer will read the “mean” value shown on the right. This is the average force for this portion of time on the graph. It should be close to the average force which you estimated. The force required to maintain a constant velocity or keep the testing material moving at a constant rate is an approximation of the kinetic friction force.
16. The Data Acquisition Engineer will record the mean.
17. Repeat steps #8 through #14 to complete three runs.
18. The Race Engineer will calculate and report the average mean of three runs. Use the calculator function on the Labquest2.
   a. Touch Home
   b. Touch Accessories
   c. Touch Calculator
   
19. Repeat the process for the other surface that your team selected.
20. The Race Engineer will inform the teacher that your team completed the data needed. The teacher will indicate whether or not to proceed to the next step.

**Collect Friction Data in Alternate Orientation**
21. Orient the block on its edge and gather data for all four materials as done earlier.
## Future of Fast Tire Pod Student Data Sheet

### Kinetic Friction

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Run #1</th>
<th>Mean Run #2</th>
<th>Mean Run #3</th>
<th>Mean Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandpaper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber</td>
<td></td>
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