# THE SPEED OF STEM

SCIENCE + TECHNOLOGY + ENGINEERING + MATH

# The Physics of Lightweighting

## STUDENT GUIDE

Name: ______________________________ Class: ____________________

## About The Dow Chemical Company

Dow's STEM mission is to build the workforce of tomorrow by empowering teachers, motivating student achievement, developing careers, and collaborating with communities to transform STEM education into a driver for innovation, manufacturing, and economic prosperity.

To live out this mission, Dow has created a growing and constantly evolving series of initiatives to support and advance STEM education. While stakeholders, target audiences, and focuses may vary, every initiative is designed to inspire conversation about STEM education, collaboration to develop innovative solutions and, as a result, transformation that will enable our nation and the world to surmount the challenges of the 21st century.

For more information on Dow's STEMtheGAP™ initiatives visit, www.dow.com/company/citizenship/stem.

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## About Richard Childress Racing

Founded in 1969, Richard Childress Racing (RCR) is one of the largest and most storied organizations in NASCAR automobile racing competition. RCR currently fields three teams in the NASCAR Cup Series and five teams in the NASCAR XFINITY Series.

On their 17-building, 52-acre campus in Welcome, North Carolina, RCR's 530 team members build race cars from the ground up in a fully-integrated vertical manufacturing operation. With a culture focused on innovation, their engineering team utilizes cutting-edge technologies to continuously improve the performance of their race cars.

Their headquarters is also home to ECR Engines, a subsidiary of RCR that provides high-performance motors to our and other Chevrolet teams in NASCAR's top three national series. ECR uses advanced technologies for research & development and engine production that has earned it more than 250 victories across multiple national motorsports series and championships in the XFINITY, Camping World Truck, and ARCA Racing Series

### Richard Childress Racing staff involved in this publication

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## Evaluation of the safety of chemicals used in this module

A Safety Data Sheet (SDS) is the main document scientists at Dow use to assess the safety of chemicals. The SDS lists any hazards associated with the chemical, including potential hazards such as what might happen if the chemical is dropped or if it comes into contact with air or water. Before carrying out an experiment, a Dow scientist refers to the SDS for every chemical he or she is going to use. This allows the scientist to decide what personal protective equipment to wear and where to carry out the reaction. Dow uses a color-coding system for every chemical. All of the chemicals in these modules belong to the green category, which is the category associated with the lowest level of risk. Dow recommends and includes appropriate safety precautions in the Stay Safe boxes in both the Teacher and Ambassador Guide and Student Guide.

# Lightweighting Module

**Safety Moment**
Science is fun but can also be dangerous. The advice in these boxes will help you stay safe.

**Did You Know?**
Interesting and fun facts related to the experiments you are carrying out.

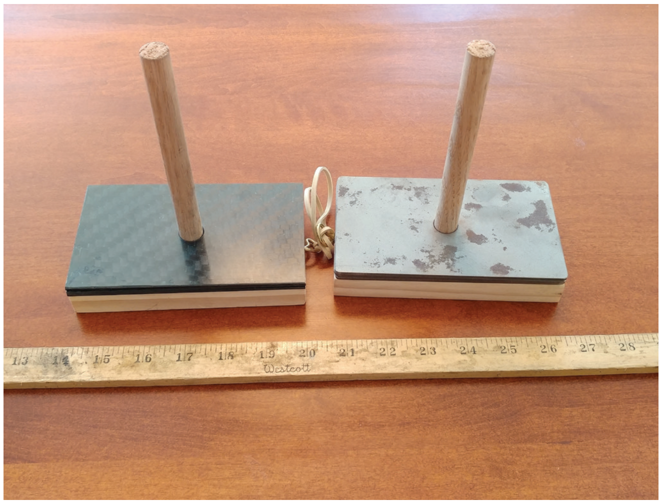
## Module Overview

Lightweighting is used in the auto industry to refer to the concept of making cars and trucks lighter in weight to improve fuel efficiency and handling. Although there is a focus on making vehicles lighter, it is imperative that safety is not sacrificed in the process. Therefore, it is important to ensure the materials used to lightweight vehicles are as strong as or stronger than the materials being replaced. This module is broken into three parts: Part 1 focuses on showing how Newton's second law ($F = m * a$, where "F" is force, "m" is mass and "a" is acceleration) applies to lightweighting, Part 2 includes testing the strength of some materials that can be used for lightweighting and Part 3 involves racing cars of different masses on racetracks.

# Part 1: Newton’s Second Law

## Lesson Overview

Newton’s second law states that force is directly proportional to mass and acceleration. That is, if the same force is applied to objects of different mass, the object with smaller mass (or the lighter object) will undergo greater acceleration.



**Safety Moment**

- Pinch point hazard: keep all fingers/hands away from point of impact
- Debris: With crash testing, there is a risk of debris or rubber band pieces flying off. Keep students observing the demo on the opposite side of the Plexiglas barrier to prevent injury
- Composite, wood and steel pieces might cause ‘slivers.’ Do not rub hands on the pieces – especially the edges.

## Crash Testing

The STEM ambassador has a set-up of 2 wooden ‘cars’ attached by a rubber band. The ambassador is going to load the cars with various materials of differing size and/or weight. When the ambassador pulls them apart and lets the cars go, there will be a point of impact where the cars crash. You will be observing where the cars impact each other, measured by the meter stick in the front. You will record the weights added to each car and collect the data on the impact point in Table 1.

## Materials

- Plexiglas barrier
- Metal brackets to stick to a table to hold up Plexiglas
- ‘Cars’ (wooden blocks with dowel rod sticking up and a hook on the side) connected by a strong rubber band(s)
- Meter Stick
- Extra Rubber Bands
- Weights to add to the cars: wooden blocks, steel, composite

# Part 1: Newton's Second Law

## Develop a Hypothesis

Before we begin the experiment, answer the questions below to "Develop a Hypothesis" about what will happen.

1. We will be using simple 'cars' attached by a rubber band to observe Newton's second law in action. If the two cars are of equal mass, will they meet in the middle? Will one travel more than the other?

2. What if the 'cars' are differing in mass? Will the 'cars' meet closer to the heavier or lighter car?

## Testing the Hypothesis

1. Take 2 wooden blocks, each with a dowel rod in the center of the block and connected with a rubber band.
2. Starting at the center of a meter-stick, pull the 2 blocks apart to an equal distance and let them go at the same time
3. Observe the point at which the two blocks collide on the meter stick, and record your results in Table 1 below.
4. Add a steel block to the top of the two base blocks
5. Repeat steps 2 and 3, and record your results in Table 1.
6. Replace one of the steel blocks with a composite block
7. Repeat steps 2 and 3, and record your results in Table 1.
8. Repeat with other combinations, and record your results in Table 1.

**Did You Know?**

"The laws of physics serve as the basics for how a race car works. Every day as an engineer, we try to make our cars faster. Therefore, I use math, physics, and many other science topics to explore high performance. Science provides the framework that we need for all of our technical advances, on and off the track."

**Brandon Thomas – Head of Vehicle Performance, Richard Childress Racing**

# Part 1: Newton's Second Law

**Table 1**

| TRIAL | MATERIAL ON CAR A, WEIGHT OF MATERIAL | MATERIAL ON CAR B, WEIGHT OF MATERIAL | LOCATION THAT THE BLOCKS MEET |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

**Did You Know?**
A Chevrolet SS Sedan weighs almost 4,000 pounds! Austin Dillon (#3 – NASCAR Cup Series) drives a Chevrolet SS that weighs approximately 3,300 pounds.

## Review Questions

1. Are things of the same size always the same weight? ______________________________

______________________________________________________________________

______________________________________________________________________

2. What did you observe as you added more weight to one side? ______________________

______________________________________________________________________

______________________________________________________________________

# Part 1: Newton's Second Law

3. Which material was the heaviest? ______________________

4. Which material was the lightest? ______________________

5. How does this relate to fuel efficiency? ______________________

______________________

______________________

______________________

______________________

______________________

# Part 2: Material Strength

## Lesson Overview

Even though polymer composite materials are lighter, they can be just as strong as steel materials of equal size. In this activity, we will be comparing the strength of materials when they are impacted by a force, called "impact testing."

**Safety Moment**

- Pinch point hazard: use caution when dropping the ball into the pipe so as to not pinch fingers.
- Debris: Impact testing requires impact of two materials. Keep all fingers away from the bottom of the tube. Ensure the guard is in place before dropping the ball.
- Composite, wood and steel pieces might cause 'slivers.' Do not rub hands on the pieces – especially the edges.
- Use caution with the edges of the plaques – they may be sharp.
- PPE: Use cut-resistant gloves when picking up broken pieces of Plexiglas to prevent cutting fingers. Students should not pick up broken pieces.

## Impact Testing

Time to break some stuff! This activity involves impact testing several materials to test how much force each material can withstand before it either breaks or bends. You will be dropping a stainless steel ball from varying heights. The ball will impact a small plaque made up of either balsa wood, aluminum, Plexiglas, or a carbon fiber composite material made at Dow Chemical. You will record your data in the table provided as well as any observations you have and compare your group's findings with the rest of the class.

# Part 2: Material Strength

## Materials

- Aluminum pipe with holes cut in every 6”
- Clear plastic container with a hole in the bottom for the bottom of the pipe
- A stainless steel ball to drop - 3/kit
- Plaques of 2 different materials 2” x 2” x 0.1” depth (Plexiglas, aluminum, composite, balsa wood - 0.125” depth) - several/kit

## Develop a Hypothesis

**1.** Feel the materials to be tested. Which material do you expect to be the strongest?

**2.** Which do you expect to be the weakest?

## Testing the Hypothesis

1. Place a plaque block of balsa wood at bottom of the aluminum pipe.
2. Cover the bottom with the clear plastic box.
3. Drop the ball from the lowest opening on the pipe (6”).
4. Inspect the material for damage.
5. Replace the plaque and repeat steps 1-4 moving up one ‘slot’ (6”) each time until material breaks or shows indentation.
6. Record height at which the material breaks in Table 2.
7. Repeat steps 1-6 for the Plexiglas, aluminum, and composite.

# Part 2: Material Strength

**Table 2**

| TRIAL | MATERIAL TESTED | HEIGHT OF BALL DROP | RESULT OF IMPACT TESTING |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

## Review Questions

1. Are 'weight' and 'strength' the same thing? ______________________________

2. Why is this important for cars? ______________________________

# Part 3: Lightweighting Application

## Lesson Overview

This activity will demonstrate how lightweighting impacts racing, and how we can use physics to understand the result. You get to be the race car driver . . . We will observe Newton's second law by racing cars!

**Safety Moment**

- Pinch point hazard: keep all fingers/hands away from the wheels of the cars

## Racing – Straight Track

Think of this activity as the time trials for the big race. Here we will drive the cars, one at a time, down the straight track in order to calculate the average speed of two different cars; one heavier than the other. Since speed is calculated by distance per time and we know how long the track is, we will be able to calculate the average speed in terms of meters per second, or m/s. We will use this data to predict the outcome of the oval track races.

**Did You Know?**

The Dow Chemical Company has been associated with racing since the 1920s. Soon after World War I, Dow developed Dowmetal pistons that produced more speed and better fuel efficiency. Dowmetal pistons were used in the car of the 1921 winner of the Indianapolis 500.

http://www.worldlibrary.org/article/WHEBN0000727360/Herbert%20Henry%20Dow

# Part 3: Lightweighting Application

## Materials

- RealFX Racing track with 2 start/finish lines
- 1 unweighted RealFX Racing car
- 1 weighted RealFX Racing car

## Develop a Hypothesis

**1.** Which car will have the higher average speed on the straight track, the heavy car or lighter car?

______________________________________________________________________

______________________________________________________________________

## Testing the Hypothesis

1. The ambassador will give 2 students remotes to the 2 cars.
2. Once the car is on the start/finish line, practice driving one time down the track following the instructions below.
    a. Driving tips:
        i. At the start, pull the trigger fully towards you.
        ii. There is no need to turn the vehicle – the car will stay in the middle of the track.
        iii. The handset gives the time, so listen closely.
3. After a trial run, drive one car down the track, not stopping or slowing down until you've crossed the finish line.
4. Record the times given by the handset in Table 3.
5. You will hear two times. Ignore the 1st time you hear when vehicle crosses the start line and record the 2nd time you hear after the car crosses the finish line.
6. Repeat steps 2 - 5 on the straight track with the second car and student
7. Calculate average speed in meters/second, then km/s, then mph: track distance is 3.5 meters.

Average Speed (Red Car) = __________ m/s * 3.6 = __________ km/hr * 0.621 = __________ mph

Average Speed (Yellow Car) = __________m/s * 3.6 = __________ km/hr * 0.621 = __________ mph

# Part 3: Lightweighting Application

**Table 3**

| RACER | TIME – RED CAR | AVG. SPEED – RED CAR | TIME – YELLOW CAR | AVG. SPEED – YELLOW CAR |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Class Average | | | | |

# Racing – Oval Track

Race Time! Here we will drive the cars, one at a time, around the oval track to apply what you've learned about how the mass of the cars affects the average speed. You will, once again, be calculating the average speed over a known distance.

## Materials

- RealFX Racing track with 2 start/finish lines
- 1 unweighted RealFX Racing car
- 1 weighted RealFX Racing car

**Did You Know?**
Modern stock cars can reach over 200 miles per hour (mph) when driving on large tracks such as in the Daytona 500.

# Part 3: Lightweighting Application

## Develop a Hypothesis

1. Which car will have the higher average speed on the oval track, the heavy car or lighter car?

## Testing the Hypothesis

1. The ambassador will give 2 students remotes to the 2 cars.
2. Once the red car is on the start/finish line, practice driving around the track continuously following the instructions below.
   a. Driving tips:
      i. In the straightaways, pull the trigger fully towards you.
      ii. When coming up to corners, slow down by easing up on the trigger. Pushing too far away from you will make the car go backwards.
      iii. The track turns to the right. To turn right, turn the tire on the remote away from you. If you need to turn left, turn the tire on the remote toward you.
      iv. The handset gives the time, so listen closely.
3. After a few times around, continue driving one car around the track. The ambassador will begin announcing times to collect.
4. Record the times given by the handset in Table 4.
5. Repeat steps 2 - 4 on the oval track with the yellow car and second student.
6. Collect the yellow car data in Table 5.

**Table 4 – Red Car**

| RACER | TIME - LAP 1 | TIME - LAP 2 | TIME - LAP 3 | AVG. TIME |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Class Average | | | | |

# Part 3: Lightweighting Application

**Table 5 – Yellow Car**

| RACER | TIME - LAP 1 | TIME - LAP 2 | TIME - LAP 3 | AVG. TIME |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Class Average | | | | |

7. Calculate average speed in meters/second, km/hr, and mph by using the average time in the tables: track distance is 3.6 meters.

   Average Speed (Red Car) = _________ m/s * 3.6 = _________ km/hr * 0.621 = _________ mph

   Average Speed (Yellow Car) = _________ m/s * 3.6 = _________ km/hr * 0.621 = _________ mph

**Did You Know?**

"Physics is everything in racing! From the aerodynamics, to the mechanics, to the tire grip, and all the way down to the weight of the car, physics is everywhere. Every part of my job requires me to consider how the physics of the car will adapt to the conditions of the track where we are racing, and how we can find the most speed possible to have the best chance of winning! There are so many variables to take into consideration, which is what I love about my job; you're constantly thinking about how each part of the car will be affected when changes or adjustments are needed."

**Ryan Sparks – Team Engineer, Richard Childress Racing**

# Part 3: Lightweighting Application

## Review Questions

1. Were the calculated average speeds of the two cars different on the straight track? If so, explain why?

2. Were the calculated average speeds of the red car different on the straight track vs. oval track? If so, explain why?

3. Were the calculated average speeds of the yellow car different on the straight track vs. oval track? If so, explain why?

4. Did the results confirm your hypothesis?

5. What are some ways we could improve lap time?

# THE SPEED OF STEM

SCIENCE + TECHNOLOGY + ENGINEERING + MATH

Thank you to everyone who contributed to the Speed of STEM Learning Modules, helping to bring to life the importance of STEM in the sport of racing.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