Gotta Have Sole

The OKC Thunder exit the court after a hard-played game, exhausted but happy. One young fan catches the attention of a member of the team who has just loosened his laces and removed his shoes. The player tosses his shoes up to the fan who clutches them tightly, beaming. A lasting memory for the fan, but as for those shoes, they pounded the court continuously for over 2 miles in just that game. Years of research and development were used to create them to perform excellently. Ever wonder how often and why NBA players change their shoes?

HERE'S WHAT YOU'LL NEED:

- **Printer paper, newspaper, or ruled paper**
- **Tape**
- **Scissors**
- **Pencil**
- **Journal**
- **Heavy books or bricks**
- **Ruler or tape measure**
- **Various recycled materials**
- **Kitchen scale**
- **Optional: stopwatch**

This activity can be done individually or with a partner, as well as in a classroom or at home.

WARM-UPS

Basketball shoes have become very popular for their style sense. They give the players a platform to drive global fashion. Some players match them to team colors or share messages bigger than the game. While basketball shoes aren't necessarily performance-enhancing, a properly designed and fitted shoe can help an athlete maximize their own physical potential due to scientific and engineering advancements in weight, design, and stability.

Let's get to the bottom of the subject—the sole. The sole has two basic parts: the insole and the outsole. We think of the insole as the soft cushioned part of the shoe. Insoles provide support and comfort for your foot. The outsole is part of the shoe we think of when we see shoe prints. The outsole is the harder, often more rubbery part of the shoe that protects your foot and provides grip.

To start, we are going to focus on the part of the sole that is between the outsole and the insole—the midsole. This area is a bridge between protection and comfort, assisting in both. This midsole protects your feet from the ground below. Technically, it could be made of anything. Think of the strongest material you can, a wood plank, steel, or other material would be excellent protection. Imagine the strength, but also the weight. Shoes can have different uses. A steel-toed boot is good in construction to maximize protection but can tire you out if you have to climb or run much during your day. You can explore this yourself without joining a construction crew. Grab something heavy, maybe a stack of books. Use one hand and hold the stack close to your chest. Now hold them out with your arm extended. Feel the difference? Imagine standing with that weight attached to your feet. Would that weight make walking or running difficult or unpleasant?

With this in mind, shoe designers find ways to balance making shoes strong while also limiting their mass and weight. For over 100 years, basketball shoes have been created with polymer soles. Polymers, or long chains of large molecules made of smaller building blocks, have a long history of providing support while limiting weight. As technology advances and we get more and more experience making shoes, the new designs hitting the courts are getting both stronger and lighter.

Let's focus on building something lightweight while still maximizing support. For this activity, you will need a journal and pencil to design your structure and record your observations. You will need multiple pieces of paper, tape, and scissors to build with. You will also need a few books.

Your goal is to build a structure from paper, 15 cm (or about 6 in) tall, that holds at least one book for a minimum of 10 seconds. You can use a stopwatch to count time down or you can use the trusty old "1, Go Thunder, 2, Go Thunder, 3, Go Thunder...."

Design before you build. With your pencil and journal, sketch shapes that are known for their strength. What shapes hold up a water tower or build strong bridges? Make sketches of as many of these things as you can for inspiration before building. Use this inspiration to design your structure.

Then, build! Make sure your structure can hold one book up for ten seconds. Redesign and rebuild until this goal is accomplished.

Once your structure can hold one book for ten seconds, see how strong your device is by weighing the book on the kitchen scale. Record this weight in your journal. Now add another book. Can your structure support this weight? If so, weigh the two books combined. Record this weight and keep going. Make observations in your journal. What parts worked well? Would you make any improvements?

GAME TIME

You have successfully made something relatively lightweight that could support some hefty books. Let's keep this research and development going as we design and build a sole for a shoe that can stand up to repeated use.

For this activity, use what you learned in warm-ups to recreate a midsole out of strong shapes. Next, search your surroundings or recycling bin for any materials that could provide a good outsole. Remember, outsoles not only provide protection from the ground, they also provide grip. Next, you'll want to create the insole. This part provides support for your foot but also comfort by providing a cushion.

The challenge is to create a combined structure with an insole, midsole and an outsole that can handle regular use. To test out the device, we will perform a repeating series of two challenges while we increase the weight. This time in addition to just supporting weight, your contraption will have to withstand force.

F(Force) = m(mass of an object/how heavy) x a(acceleration/how fast)

First challenge: drop a book from 30 cm (~12") onto the device 10 times. If it stands up to the challenge, move on to the second part of the test. If not, re-design your contraption by keeping what works and re-designing what doesn't.

Second challenge: with a book resting on top of the "insole" of the contraption, drop the book and "sole" 30 cm (~12") to the ground so they fall together and land flat. Repeat this 10 times. If it stands up to the challenge, repeat the first part of the challenge but add another book. Like in the warm-ups, record the weight in your journal so you can measure your success and review your findings. Continue this process as time allows.

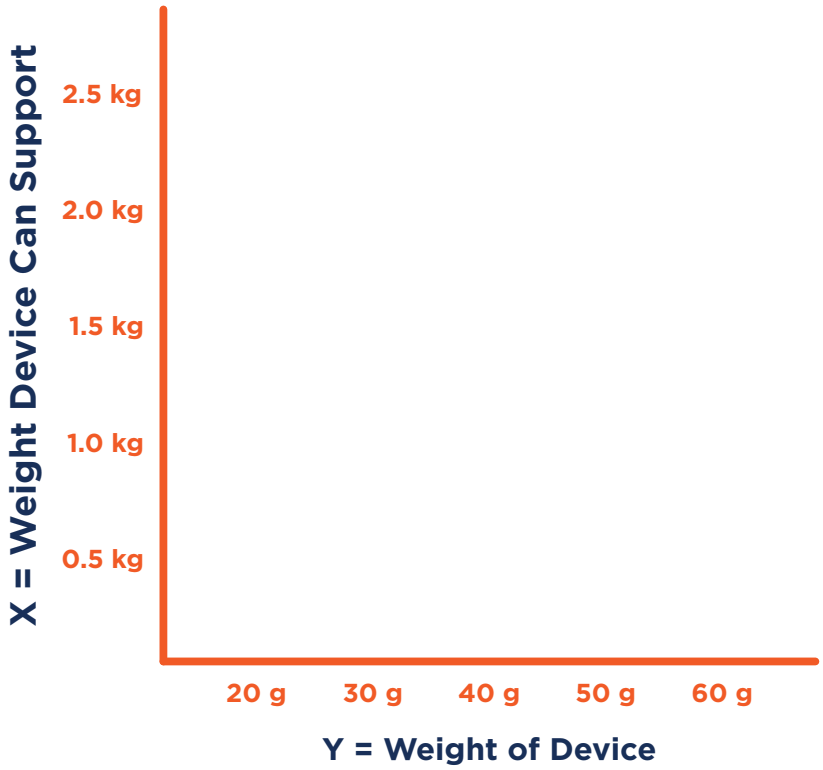
ANALYZE THE REPLAY What happened?

Through this process, you may have found some designs and shapes that worked well. While reviewing your sole design, recall other places you have seen these shapes. Are these shapes recognizable in other structures? Could you see these structures being used in a real shoe design? Why or why not? Paper may not be the most practical material for a shoe but what material could work better? How much stronger did a fragile material become when combined with other materials than when it was alone? Did certain shapes seem to make materials stronger? What does that tell you?

Engineers use the **strength-to-weight ratio** to find things that are both strong and lightweight. By dividing the weight that your device held before it failed by the weight of the device itself you have found the strength-to-weight ratio. A device that holds up 10 kg and weighs 4 kg would have a strength

to weight ratio of 2.5 (10 divided by 4), but would not be as good as something that only holds up 10 kg but weighs just 0.5 kg. Its strength to weight ratio would be 20! (10 divided by 0.5)

You can also use the following graph. Since the strength to weight ratio requires something that can hold a lot of weight while not weighing very much itself, the plot points for a good device will fall higher on the X axis but not as far out on the Y axis.



OVERTIME
Let's take it further.

Your design has come a long way, from a sketch inspired by structural shapes you had noticed around you, all the way to a contraption that went through all sorts of tests. Now, can the sole you designed and built support your weight? How might you redesign or reinforce your sole to make this possible?

In addition to **strength-to-weight ratio**, other things like **elasticity** and **surface area** of the outsole are important because this is where the shoe makes contact with the floor. Some shoes have hard rubber and a deep tread or pattern on the bottom that helps give you more grip if the ground is wet or muddy. Some shoes have deep grooves or even metal spikes to bite into the surface and give more grip. Other shoes have soft polymer compounds that look smooth but are able to fill into tiny imperfections in the floor and stick to them to grip smooth floors better.

To see how important surface area is, try this neat trick: Stand on eggs without breaking them! Eggs are strong, dome-shaped structures that can hold a lot of weight as long as it is spread around the shell evenly and not concentrated on one point. If you step on one egg you will crush it, but spread your weight evenly across the surface of a dozen eggs and they can hold your weight. Take a carton full of eggs and an empty egg carton. Open the full egg carton, leave the eggs in the little cups, but carefully make sure all of the eggs are pointed in the same direction and similar-sized eggs are nearest to each other. Have two friends hold you up by your arms and put your feet lightly on the egg cartons. Then, slowly and evenly, transfer all your weight onto the eggs and they will not break.

COACH'S CORNER
Additional information and explanations for parents and educators

Thunder players will often run more than 3 km or even 4 km (2.5 miles a game). That means feet hitting the floor 5,000 times! That doesn't even count the numerous jumps or quick changes of direction that apply even more stress to a shoe than a normal step during a run. Hundreds of pounds of force are applied to the ground to produce a jump that will likely be many times the weight that the contraptions we built could handle. Even with the advanced technologies and materials that go into a basketball shoe, many players will change out their shoes for each game, and even the longest-lasting shoes will only be worn in 6 or 7 games. A human foot is not completely flat so the wear on the shoe is uneven, creating stressors that can make a different part of the shoe fail. A basketball shoe is a tool. It won't make or break the performance of the wearer. If it is thoughtfully designed and built, though, it can facilitate a player's ability to perform at an extremely high level throughout an entire season.

DO YOU WANT TO LEARN MORE?

Research: force, pressure, structural engineering, surface area

OKLAHOMA ACADEMIC STANDARDS – SCIENCE

Standard	2nd Grade	4th Grade	5th Grade
2.PS1.1: Material properties	•		
2.PS2.1: Material testing	•		
4.PS3.3: Collisions		•	
4.PS3.4: Energy transfer		•	
5.PS1.3 Material science			•