SCIENCE AT HOME

SPRING FORCE PHYSICS

GRADE: 12

SPH4U
SUBJECT: PHYSICS
STRAND: DYNAMICS, ENERGY AND MOMENTUM
TOPIC: SPRING FORCE PHYSICS (HOOKE'S LAW AND APPLICATIONS)
EXPECTATIONS: SPH4U: B2.3, B2.4, B2.5, C3.1
VIDEO: youtu.be/SF6XpyWoixA

INTRODUCTION:

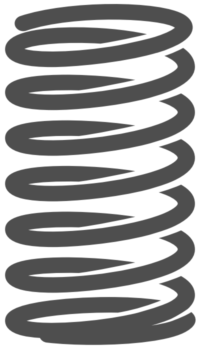
A force is a push or pull that, if acting alone, will cause a change to the way an object is moving.

Gravity, a pulling force, is often the first one that we learn about. Earth's gravity pulls objects toward the Earth's centre. We calculate the force of gravity "near Earth," or "F_g," as $F_g = mg$, where m is an object's mass, and g is the constant acceleration due to gravity experienced by objects "near" the surface of the Earth. Because the force of gravity near Earth depends only on the object's mass and not on its position, we say that it's a constant force. Moving an object up or down, left or right, won't change the gravitational force acting on it.

The "normal force" is a push that prevents objects from moving through one another. When you set a book on a table, gravity pulls the book downwards, but the normal force from the table pushes it back up. If these forces — gravity and the normal force — are in balance, the book won't move.

Gravity is a constant and fundamental force, but what about the normal force? Are all forces constant, or do they depend on position? And what is the normal force really?

To answer these kinds of questions, physicists build simple models. They use their models to make predictions and then test those predictions with experiments. Models are constantly tested. When a model fails to make a prediction, it needs to be improved, or replaced altogether.



In this activity, you will be creating a model for how a certain force — the spring force —behaves, and see how it relates to the normal force.

ACTIVITY: Investigate spring force

TIME: 30 minutes

SAFETY:

Wear glasses, sunglasses or safety goggles to protect your eyes in case an elastic breaks.

WHAT YOU NEED:

- Ruler
- Elastic band, hair tie, spring (the easier to stretch, the better)
- Banana holder or another stand that an elastic can be hung from
- Container (an envelope, for instance) to hold mass

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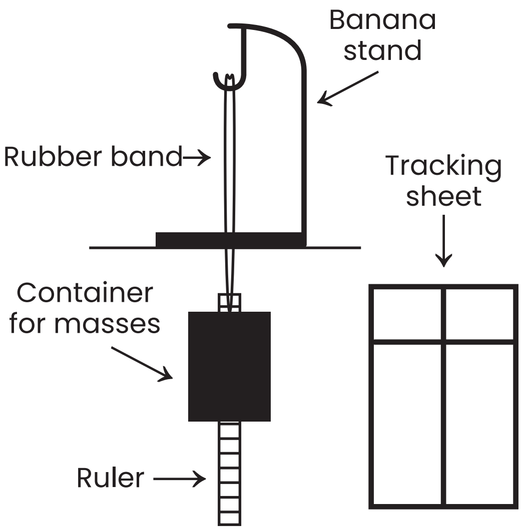
WHAT YOU NEED (continued):

- Nickels or other objects with masses identical to each other (like coins or marbles)
- Tape
- Paper
- Pencil
- Calculator

WHAT YOU DO:

- Attach an elastic to the banana holder or stand.
- To the other end of the elastic band, attach the container, so that it hangs down.
- Use a ruler to measure the starting length of the elastic.
- Add a weight to the container and observe what happens to the elastic and the container. Record the length of the elastic.



- Keep adding weights. Measure the length of the elastic each time. If you're okay with breaking your elastic, keep adding weights, and record the point when it breaks.
- Graph your results with the length of the elastic on the x-axis and the elastic force on the y-axis.

  Hint: To determine the elastic force, draw a free-body diagram, showing the magnitude and direction of all the forces acting on the container.
- Looking at your graph, try to come up with a simple equation for the elastic or spring force as a function of the elastic's length. What kind of function does it look like?
- Using your graph, try to come up with a simple equation for spring force. When does the equation hold and when does it break? How does your equation for spring force compare to the equations for other forces you've learned about — for instance, gravity?

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WHY THIS MATTERS:

It turns out that spring force is not a constant force — it depends on the amount that an object stretches or compresses. This relationship is described by Hooke's Law: $F_s = kx$. The spring force (F_s) is equal to the distance stretched or compressed (x) multiplied by a spring constant (k). It's important to remember that physicists don't come up with these equations off the top of their heads; it was hypothesized, tested and refined through experiments like the one you just did.

As you continue in your studies, you will learn that other important forces, like universal gravitation and the electrostatic force, are not constant.

ACTIVITY: Investigate how all materials behave like elastics and springs

TIME: 15 minutes

SAFETY:

Wear glasses, sunglasses or safety goggles to protect your eyes in case something breaks.

WHAT YOU NEED:

- Foam blocks
- Paper towel rolls
- Wooden, plastic or metal board
- Any long cylinder or rectangular prism (for instance, sticks, kitchen utensils, pencils, etc.)
- Water

Note: In this activity, you will be bending or stretching objects, possibly to their breaking point. Make sure you select a couple of objects that you are okay with breaking (for instance, sticks from outside).

WHAT YOU DO:

- All objects, even ones we think of as rigid, exhibit spring properties when you stretch or compress them before they eventually break.
- Select an object and apply a gentle force to it and then release. Watch how the object bends and then returns to its original shape, just like an elastic.
- Apply more and more force to the object. Does it still snap back to its original shape when you let go?
- Apply enough force so that the object does not snap back to its original shape. (Make sure you're using objects that you don't mind breaking). When does it reach a breaking point? Where does it break?
- Repeat the experiment using other materials. Which ones can handle the most force before they deform or break? Which ones can bend or compress the furthest and still return to their original shape?

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WHY THIS MATTERS:

Every object, even rigid things like tables and floors, behaves like a spring if you look closely enough. When you stand on a floor, it bends or compresses like a spring and exerts a force back on you. We usually call this the "normal force," but as you can see, the normal force is not a fundamental one. In this case, the normal force is really a spring force caused by the compression of the floor.

Eventually, objects will reach a breaking point where they stop acting like springs. Materials scientists study materials to determine their spring constants and the maximum forces they can withstand before they deform or break.

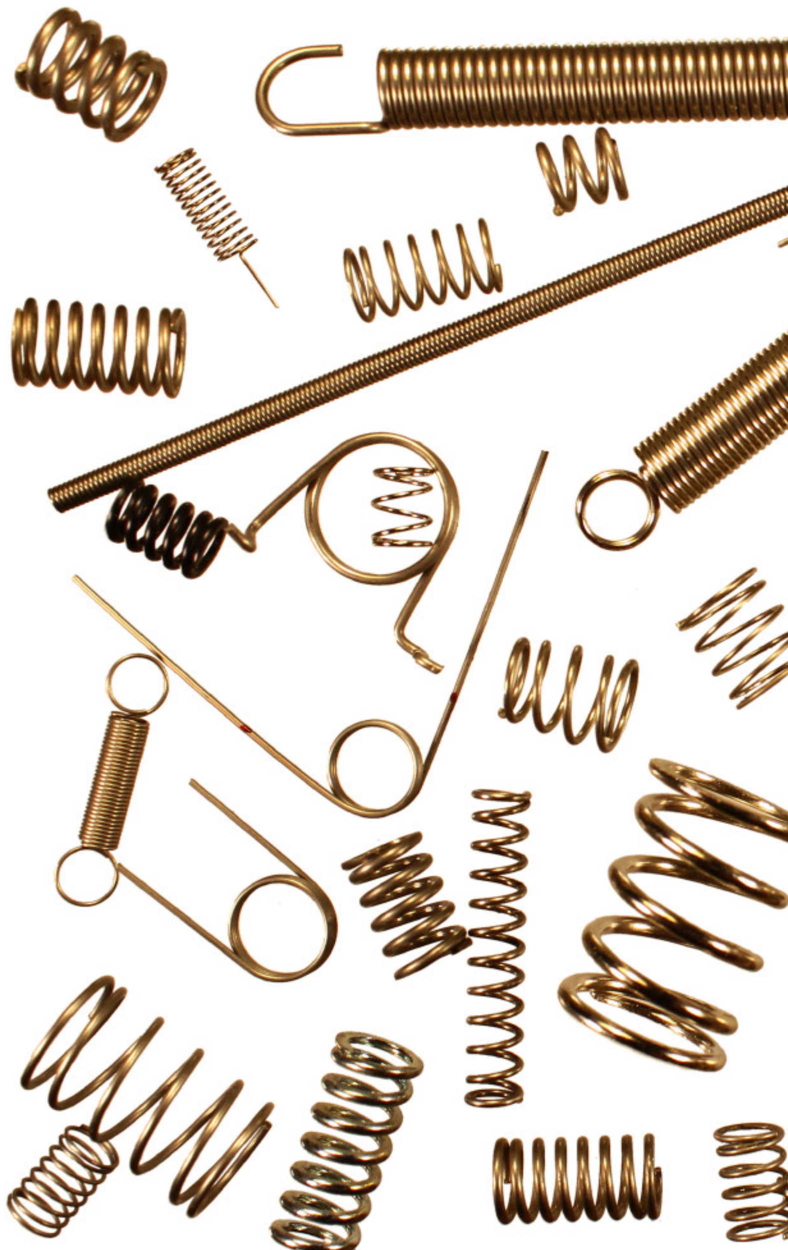
Once you've determined this maximum force, you can use that information (along with "inelastic collisions" and "conservation of energy") to figure out, for instance, how fast you need to swing your arm to break boards the way martial artists do!

MORE ONLINE:

How to determine the spring constant
https://www.youtube.com/watch?v=tdy_wHZfdTo

Normal Force Demo
https://www.youtube.com/watch?v=7I4iFXN0at0&feature=youtu.be

Hooke's Law and Young's Modulus
https://www.youtube.com/watch?v=qvcpeA5pBH0&feature=youtu.be



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