RAFT IDEAS

Topics: Springs, Hooke's Law, Gravitational forces, Equilibrium

Materials List
- ✓ Coiled spring, flexible, metal or plastic
- ✓ Ball

This activity can be used to teach:
Next Generation Science Standards:
- Forces & Motion (Grade 3, Physical Science 2-1, 2-2; Middle School, Physical Science 2-2; High School, Physical Science 2-1)
- Kinetic and Potential Energy (Grade 4, Physical Science 3-1; Middle School, Physical Science 3-2, 3-5)
- Gravity (Grade 5, Physical Science 2-1)
- Science & Engineering Practices (Grades 2-12)

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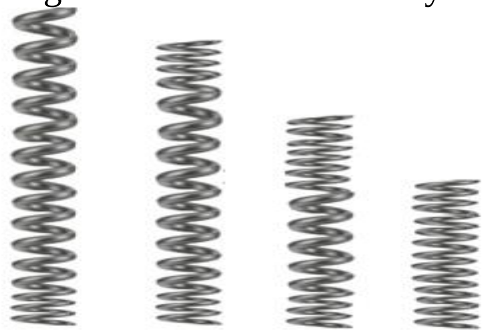
Gravity Defying Spring

Drop the Spring and Observe Momentary Weightlessness!



Explore what happens when a coiled spring is dropped. Expectations are sometimes different from reality. These discrepant events can create memorable impressions and heighten student interest.

To Do and Notice

1. With arm extended hold the spring's topmost coil in one hand, between the thumb and middle/index fingers and allow the remaining coils to hang downward.
2. Wait until the bottom of the stretched out spring comes to rest or until the bottom's bouncing up and down is minimal. Release the coiled spring and observe (watch and listen) carefully. Observe the relative positions of the top, middle, and bottom coils as the spring drops.
3. Does the bottom of the spring fall as expected?
4. Repeat steps 1 to 3 except hold, or have another person hold, a ball next to the bottom of the spring and release both simultaneously. Does the ball hit the floor before, after, or at the same time as the spring?
5. Repeat steps 1 to 3 except hold the ball next to the top part of the spring and drop both at the same time. Does the ball hit the floor before, after, or at the same time as the spring?
6. Repeat steps 1 to 3 except hold the ball near the middle of the stretched-out spring and drop both at the same time. Does the ball hit the floor before, after, or at the same time as the spring?

The Science Behind the Activity

This activity combines Newton's second law of motion, the effect of gravitational forces, and Hooke's law, which deals with the elastic forces on springs.

- Newton's Second Law of Motion relates to how velocity changes when forces are applied to an object:
  $F = ma$ where F = force applied to an object
  m = mass of the object
  a = acceleration of the object

- Hooke's Law of Elasticity states that the extension of a spring is in direct proportion with the load added to it as long as the load does not exceed the elastic limit.
  $F = -k\,x$ where F = restoring force exerted by the material
  k = spring constant
  x = displacement from the equilibrium position
  The minus sign indicates the force's direction is the opposite of x.

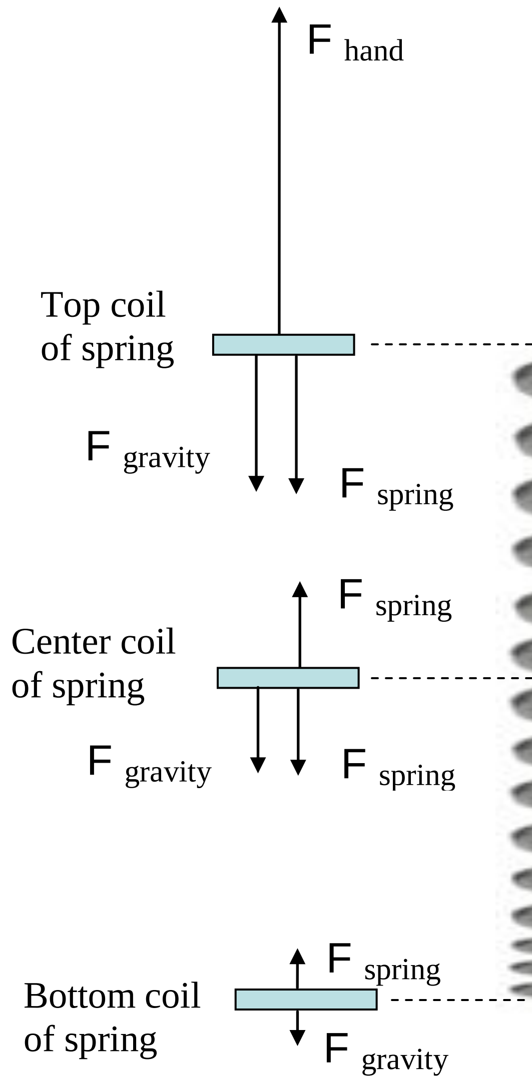
Written by Gus Liu (RAFT)

Explanation for the "delayed" response of the bottom of the spring (see steps 3 and 4 of **To Do and Notice**): The bottom part of the spring does not drop immediately after the top is released. Surprisingly, the bottom part appears to be suspended in midair, even if for only a fraction of a second. Only when the top drops down and the coils collapse completely does the bottom of the spring start to move downward. When the bottom of the spring has stopped bouncing up and down the gravitational force pulling downward on the bottom coil is balanced by the upward pull of the coils above (the restorative force). The forces are in equilibrium. When the spring is released, the upward force on the bottom coil, exerted by the coils above, remains unchanged as the top coils fall. The bottom of the spring remains stationary until the coils collapse together. The upward pull on the bottom coil then become zero and the whole coil accelerates towards the ground.

Explanation for the "accelerated" falling of the top of the spring (see step 5 of **To Do and Notice**): When the top of the spring is held the downward gravitational force combines with the downward pull of the rest of the spring's coils on the top coils (the restorative force). When the top coil is released, this combined force results in a higher rate of acceleration than if only gravity was pulling the top coils downward. Thus the top of the spring accelerates downward at a higher rate than the falling ball.

Explanation for "normal" falling of the center part of the spring (see step 6 of **To Do and Notice**): At equilibrium, the upward pulling (restorative) force of the stretched coils above the center of the spring is balanced by the downward pulling (restorative) force exerted by the coils below the center. The upward and downward "springy" forces balance each other leaving just the force due to gravity pulling downward on the center of the spring. When released, the ball and the center of the spring both experience the same gravitational force and will fall to the ground at the same rate of acceleration.

Force Diagram of the spring at equilibrium, with a hand holding on to the top coil of the spring:



Taking it Further

- Experiment with other springs, to see if coils with different stiffness make a difference in the responses.
- Use two identical springs, but add a weight to the bottom of one of them. Observe what happens to the rates of acceleration for the top, the bottom and the center part of the springs.

Web Resources (Visit www.raft.net/raft-idea?isid=573 for more resources!)

- Watch a video of a spring falling in slow motion -http://www.youtube.com/watch?v=iSHJKvZBJvk&NR=1