ANSWER KEY. Values match the simulation readouts for the settings given in each step.

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Hooke's Law Virtual Lab

Physics | ANSWER KEY

Open **activities.zornscience.org/hookes-law-lab/** and follow each step. Use g = 9.81 m/s^2. Show your work with units.

Objective

Find the **spring constant** of a spring from force and extension data, then find which variables change the **period** of a mass bouncing on a spring.

NGSS alignment: HS-PS2-1. Analyze data to support the claim that Newton's second law describes the relationship among the net force on an object, its mass, and its acceleration. HS-PS3-2. Develop and use models to show that energy can be stored by position (elastic potential energy) and as motion (kinetic energy).
Practices and concepts: Analyzing and interpreting data; Using mathematics; Patterns; Cause and effect.

Meet the simulation

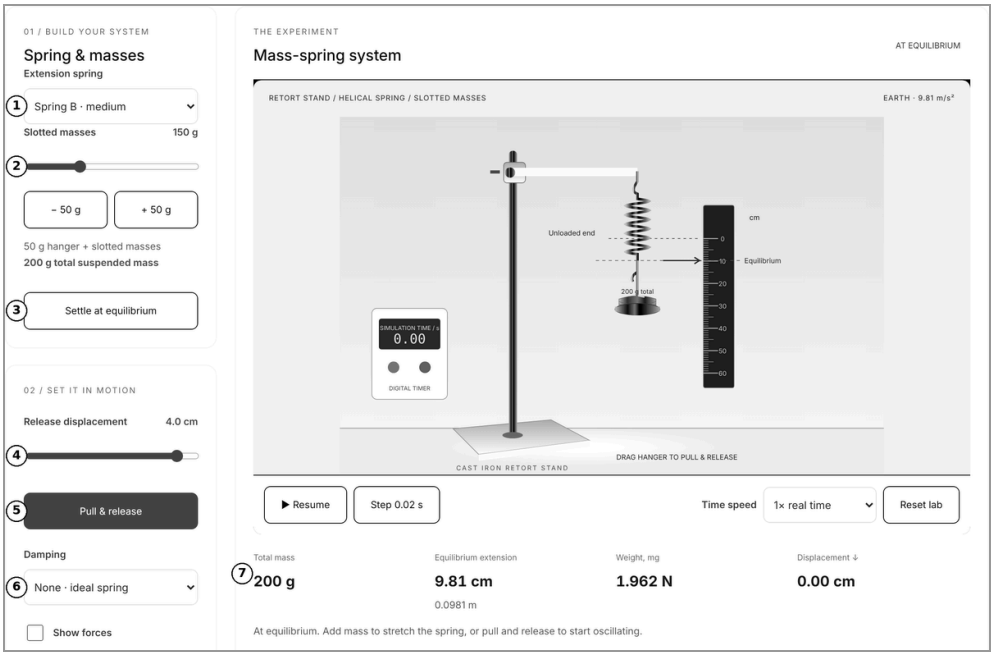


Figure 1. The Hooke's Law lab. The dark scene is shown inverted for printing.

1. Spring A (soft), B (medium), or C (firm).
2. Slotted masses. The 50 g hanger is added for you. The −50 g and +50 g buttons also work.
3. Stops the motion at equilibrium.
4. How far you pull the mass before release.
5. Pulls and releases the mass.
6. Damping (friction). Keep it on None unless a step says otherwise.
7. Readouts: total mass, extension, weight, displacement.

Pre-lab

1. Hooke's law is F = kΔL. What does each symbol mean? Give the SI unit of k.

F = spring force (N), k = spring constant (stiffness), ΔL = extension, how far the spring stretches (m). The unit of k is N/m.

2. A 0.300 kg mass hangs at rest from a spring and stretches it 0.150 m. Calculate the spring constant. (At rest, the spring force equals the weight.)

k = mg / ΔL = (0.300 kg)(9.81 m/s^2) / 0.150 m = 2.943 N / 0.150 m = <u>19.6 N/m</u>

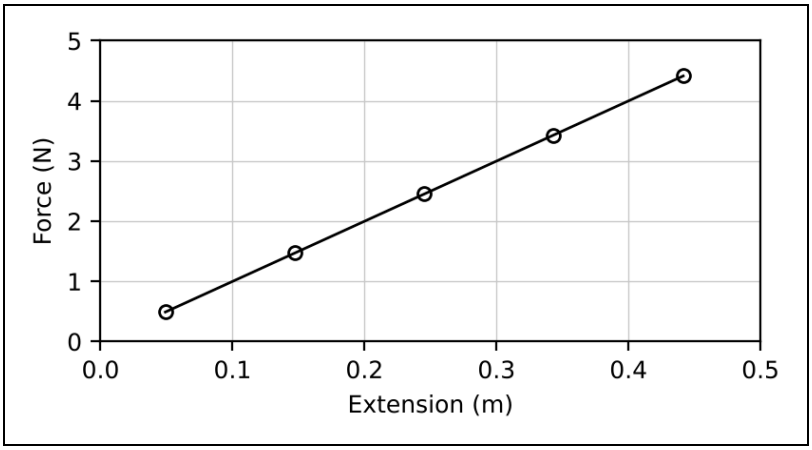
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Part A. Force and extension for Spring A

1. Choose **Spring A · soft**. Keep Damping on **None**. Do not check "Show spring constant".
2. Set each slotted mass below. Record the total mass, the weight (mg), and the equilibrium extension in meters (the small number under the cm value).

Trial	Slotted masses (g)	Total mass (g)	Weight, mg (N)	Extension ΔL (m)	k = mg / ΔL (N/m)
1	0	**50**	**0.491**	**0.0491**	**10.0**
2	100	**150**	**1.472**	**0.1472**	**10.0**
3	200	**250**	**2.453**	**0.2453**	**10.0**
4	300	**350**	**3.433**	**0.3433**	**10.0**
5	400	**450**	**4.415**	**0.4415**	**10.0**

3. Graph force (y-axis) against extension (x-axis). Label both axes with units and draw a line of best fit. Calculate the slope.



Straight line through the origin. Slope = ΔF / ΔL = (4.415 N − 0.491 N) / (0.4415 m − 0.0491 m) = <u>10.0 N/m</u>

4. What does the slope of your graph represent? Compare trials 1 and 3: when the force became 5 times larger, what happened to the extension?

The slope is the spring constant, k = 10.0 N/m. The extension also became 5 times larger (0.0491 m to 0.2453 m). Force and extension are directly proportional.

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Part B. Compare the three springs

1. Set the slotted masses to **200 g** (250 g total). Choose each spring below and record the extension in meters.
2. Calculate k for each spring. Then check **Show spring constant** to check your answers.

Spring	Weight, mg (N)	Extension ΔL (m)	k = mg / ΔL (N/m)
A · soft	**2.453**	**0.2453**	**10.0**
B · medium	**2.453**	**0.1226**	**20.0**
C · firm	**2.453**	**0.0818**	**30.0**

5. Show your calculation of k for Spring C. On a force vs. extension graph, which spring would have the steepest line? Explain.

k = 2.453 N / 0.0818 m = 30.0 N/m. Spring C has the steepest line because the slope equals k. A stiffer spring needs more force for each meter of stretch.

Part C. Mass and period

1. Uncheck "Show spring constant". Choose **Spring B**, Damping **None**, Release displacement **4.0 cm**.
2. Set each slotted mass below and select **Pull & release**.
3. Wait for the bracket on the Position vs. time graph. Record the **Measured period** (marker 2).

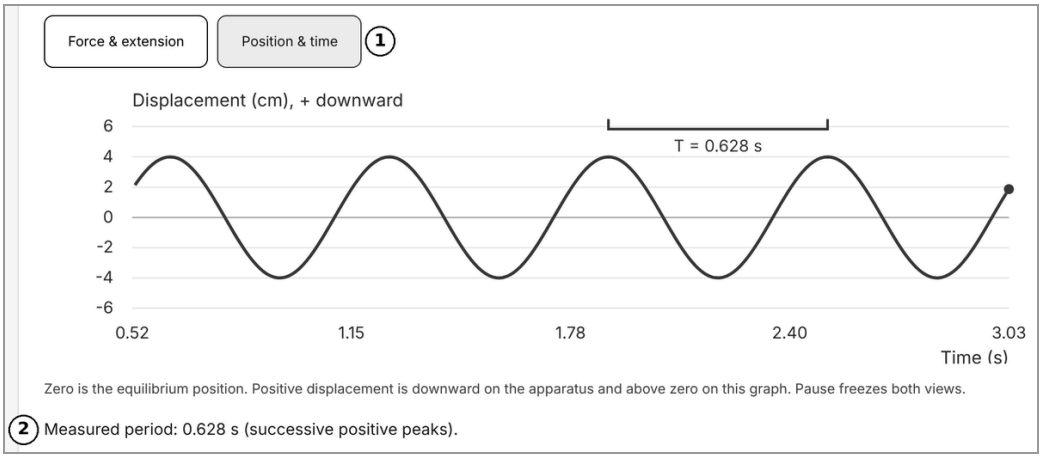


Figure 2. Position vs. time graph after release. One period is the time from one peak to the next.

Trial	Slotted masses (g)	Total mass m (kg)	Measured period (s)	Predicted T = 2π√(m/k) (s)
6	50	**0.100**	**0.444**	**0.444**
7	150	**0.200**	**0.628**	**0.628**
8	350	**0.400**	**0.889**	**0.889**

6. Show the predicted period calculation for trial 7. Then compare trials 6 and 8: the mass became 4 times larger. By what factor did the period change?

$T = 2\pi\sqrt{(0.200\ kg / 20.0\ N/m)} = 2\pi\sqrt{(0.0100\ s^2)} =$ 0.628 s.
0.889 s / 0.444 s = 2.00. Four times the mass doubles the period, because T depends on √m.

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Part D. Amplitude and damping

1. Keep Spring B and set the slotted masses to **150 g**. Use Damping **None**.
2. Release from **2.0 cm**, then from **4.0 cm**. Record each measured period.
3. Keep 4.0 cm. Change Damping to **Light**, release, and record. Repeat with **Strong**.

Release displacement (cm)	Damping	Measured period (s)	What happens to the peaks?
2.0	None	**0.628**	**Stay 2 cm high**
4.0	None	**0.628**	**Stay 4 cm high**
4.0	Light	**0.629**	**Shrink slowly**
4.0	Strong	**0.636**	**Shrink quickly to 0**

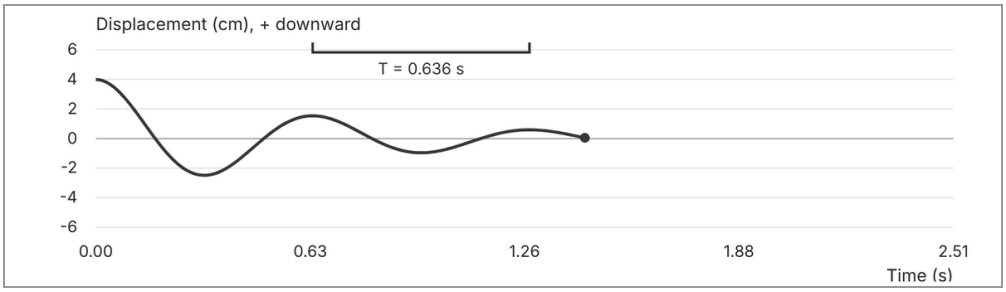


Figure 3. Strong damping, paused about 1.3 s after release.

7. Does doubling the release displacement (amplitude) change the period? Why does a larger pull not take longer, even though the mass travels farther?

No, the period stays 0.628 s. A larger pull stretches the spring more, so the restoring force is larger and the mass moves faster. The extra speed makes up for the extra distance.

8. Using the 4.0 cm, no damping release, calculate the elastic potential energy at the release point with PE = ½kx^2. With strong damping, where does this energy go?

PE = ½(20.0 N/m)(0.040 m)^2 = <u>0.016 J</u>. Damping (like air resistance) changes mechanical energy into thermal energy, so the peaks get smaller until the mass stops at equilibrium.

9. The simulation uses an ideal spring. Name two ways a real spring in a classroom lab would behave differently.

A real spring has mass (which makes the period a little longer), there is always some air resistance and friction (so it slowly stops), and too much mass can stretch it past its elastic limit so it stays bent.

Conclusion

10. Write a claim that answers the objective: what is the spring constant of Spring A, and which variables change the period? Support it with evidence (specific numbers) and explain your reasoning with F = kΔL and T = 2π√(m/k).

Claim: Spring A has k = 10.0 N/m. The period depends on mass and spring constant, not on amplitude.
Evidence: The force vs. extension slope was 10.0 N/m. On Spring B, 0.100 kg to 0.400 kg raised T from 0.444 s to 0.889 s, but 2.0 cm and 4.0 cm both gave 0.628 s.
Reasoning: Force is proportional to extension, so the slope is k. More mass has more inertia and a stiffer spring gives a larger restoring force, so T = 2π√(m/k). Amplitude is not in the equation.

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