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Laboratory Report

Evaluating the Spring Constant Using Static and Dynamic Methods

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ABSTRACT

In this experiment, we determined the spring constants($\boldsymbol{k}$) of **green and blue** springs (Figure 1) using two methods: **the static method** and the **dynamic method**. In the static method, we measured the elongation of the spring due to various hanging weights and used **Hooke's Law** to calculate the spring constant. In the dynamic method, we observed the **period of oscillation** of the springs under different masses and used the relationship between mass and oscillation period to determine the spring constant. The results were compared to standard values (Figure 2), with errors calculated to assess accuracy. Our findings showed that both methods provided reasonably close approximations to the expected values, with minor discrepancies likely due to measurement uncertainties.

FIGURE 1. *Opened spring set showing red, blue and green spring with different spring constants.*

FIGURE 2. *The label indicating different spring constants for each color-coded spring: Red (10 N/m ±5%), Blue (20 N/m ±5%), and Green (40 N/m ±5%).*

THEORETICAL BACKGROUND

A **spring** is an elastic object that deforms under force and returns to its original shape when the force is removed. The stiffness of a spring is measured by its **spring constant** ($\boldsymbol{k}$), which quantifies how much force is required to stretch or compress the spring by a unit length.

The relationship between force and displacement in a spring is described by **Hooke's Law**, which states:

$$F_S = -kx$$

where:

- $\boldsymbol{F_S}$ is the restoring force exerted by the spring (N),
- $\boldsymbol{k}$ is the spring constant (N/m),
- $\boldsymbol{x}$ is the displacement from the natural length of the spring (m).

The **negative sign** indicates that the restoring force is always directed **opposite** to the displacement. A **larger $\boldsymbol{k}$** value means a **stiffer spring**, while a **smaller k** value means a more **flexible spring.**

In this experiment, we determined k for two different springs using two different methods:

1. **Static Method**: Measuring elongation under different weights.
2. **Dynamic Method**: Using **simple harmonic motion (SHM)** to calculate $\boldsymbol{k}$ based on the oscillation period.

STATIC METHOD

In the static method, we determined the spring constant by measuring how much the spring elongated (Diagram 1) when different masses were suspended from it.

Since the weight of an object is the force due to gravity, we express it as:

$$F = mg$$

where:

- $\boldsymbol{m}$ is the mass of the hanging object (kg),
- $\boldsymbol{g} = 9.8\ m/s^2$ is the acceleration due to gravity.

At equilibrium, the downward gravitational force (mg) is balanced by the upward restoring spring force(F_S) , so:

$$mg = kx$$

Rearranging for k, we get:

$$k = \frac{mg}{x}$$

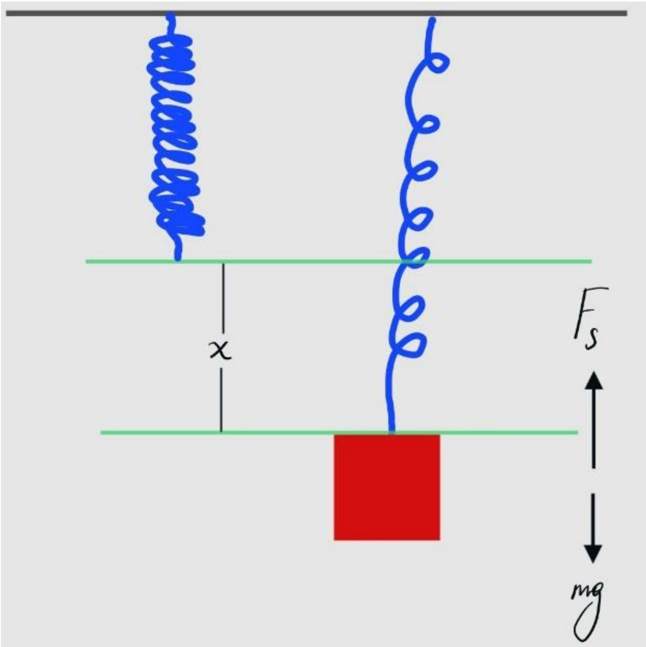


DIAGRAM 1. *Diagram illustrating the static method for determining the spring constant. A mass is suspended from a vertical spring, causing an elongation $\boldsymbol{x}$. The forces acting on the system include the restoring force of the spring ($\boldsymbol{F_S}$) and the gravitational force ($\boldsymbol{mg}$).*

To determine $\boldsymbol{k}$ **graphically**, we can plot $\boldsymbol{mg}$ (force) on the **vertical axis (y-axis)** and **x** (elongation) on the **horizontal axis (x-axis)**. The **slope** of this graph represents the spring constant k:

$$Slope \llcorner_x^{mg} = k_{static}$$

By applying **linear regression to our data**, we can obtain a best-fit equation, **where the slope of the line** gives the **experimentally** determined value of **k**.

DYNAMIC METHOD

In the dynamic method, we determined the spring constant by analyzing the simple harmonic motion (**SHM**) of a mass oscillating on a spring. When a mass m is attached to a vertical spring and displaced slightly, it oscillates with a periodic motion characterized by a **time period (T^2).**

For a mass-spring system undergoing SHM, the period is given by:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Squaring both sides:

$$T^2 = \frac{4\pi^2 m}{k}$$

From this equation, if we plot **mass ($\boldsymbol{m}$)** on the **vertical axis** and $\boldsymbol{T^2}$ on the **horizontal axis**, the **slope** of this graph should be:

$$Slope \llcorner_{T^2}^{m} = \frac{\mathrm{k}}{4\pi^2}$$

Thus, the spring constant k can be found by rearranging:

$$k_{dynamic} = 4\pi^2 \times Slope \llcorner_{T^2}^{m}$$

PROCEDURE

MATERIALS:

1. Green and blue springs (Figure 1)
2. Support stand with clamp (Figure 3)
3. Meter stick
4. Set of known masses
5. Stopwatch
6. Data recording sheet

SETUP:

The setup consisted of a **support stand** with a clamp to hold the springs securely. For the static method, different masses were attached to the bottom of the spring, and elongation was measured using a meter stick. For the dynamic method, the spring was slightly displaced and released to oscillate, with the time for ten oscillations recorded using a stopwatch.

FIGURE 3.
A support stand with a mounted ruler.

EXPERIMENT:

Static Method:

1. The **natural length** of each spring was measured.
2. Masses were incrementally added, and the corresponding elongations were recorded.
3. A **scatter plot** of **weight vs. elongation** was created, and the spring constant was determined from the slope.

Dynamic Method:

1. A mass was attached to the spring, displaced slightly, and released to oscillate vertically.
2. The time for **ten** complete **oscillations ($10T$)** was measured and divided by ten to find the period T .
3. The squared period T^2 was plotted against mass m, and the spring constant was determined using the slope relationship:

$$k_{dynamic} = 4\pi^2 \times Slope \llcorner_{T^2}^{m}$$

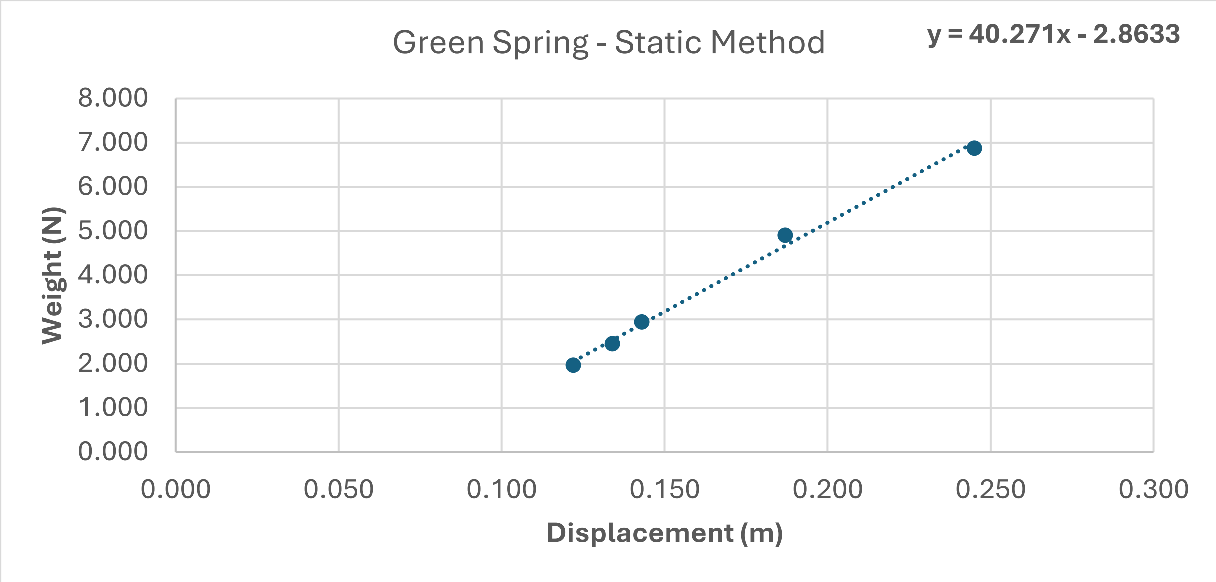
DATA & ANALYSIS

The collected data, calculations, and graphical analysis are presented below.

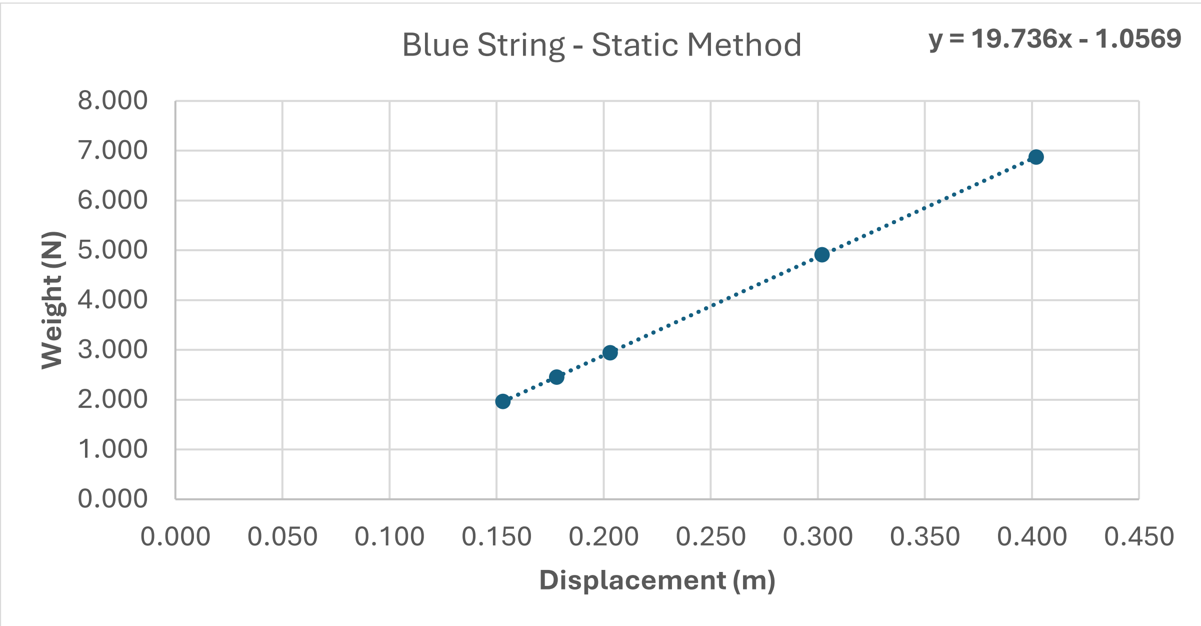
STATIC METHOD

Static Method						
Spring	Data point	x (m)	m (kg)	Weight (N)	Natural length (m)	Extended spring length under weight (m)
Green	1	0.122	0.200	1.964	0.034	0.156
	2	0.134	0.250	2.455	0.034	0.168
	3	0.143	0.300	2.946	0.034	0.177
	4	0.187	0.500	4.910	0.034	0.221
	5	0.245	0.700	6.874	0.034	0.279
Blue	1	0.153	0.200	1.964	0.034	0.187
	2	0.178	0.250	2.455	0.034	0.212
	3	0.203	0.300	2.946	0.034	0.237
	4	0.302	0.500	4.910	0.034	0.336
	5	0.402	0.700	6.874	0.034	0.436

TABLE 1. *This table summarizes the elongation measurements of green and blue springs when subjected to different known weights. The displacement (x) is calculated as the* ***difference*** *between the* ***extended spring length*** *and its* ***natural length.***



GRAPH 1. *Graph of applied weight vs. displacement for the green spring using the static method data derived from Table 1and including the best fit line equation y = 40.271x - 2.8633. The slope of the best-fit line represents the spring constant k, calculated as 40.271 N/m, which is close to the standard value of 40 N/m.*



GRAPH 2. *This graph illustrates the relationship between the applied force (weight) and the resulting displacement for the blue spring. The linear trend confirms Hooke's Law with a calculated spring constant of 19.736 N/m derived from the slope of the best-fit line. The slight y-intercept deviation suggests minimal systematic error, potentially due to measurement uncertainties. The **high correlation** of the data points to the trendline further **validates the experimental procedure**.*

The error percentage was calculated using the formula:

$$\% \, error = \left| \frac{Experimental\,Value - Standard\,Value}{Standard\,Value} \right| \times 100$$

Which led us to a table below:

Static Method			
Spring	k Standart Value	k Experimental Value	Error
Green	40	40.271	0.68%
Blue	20	19.736	1.32%

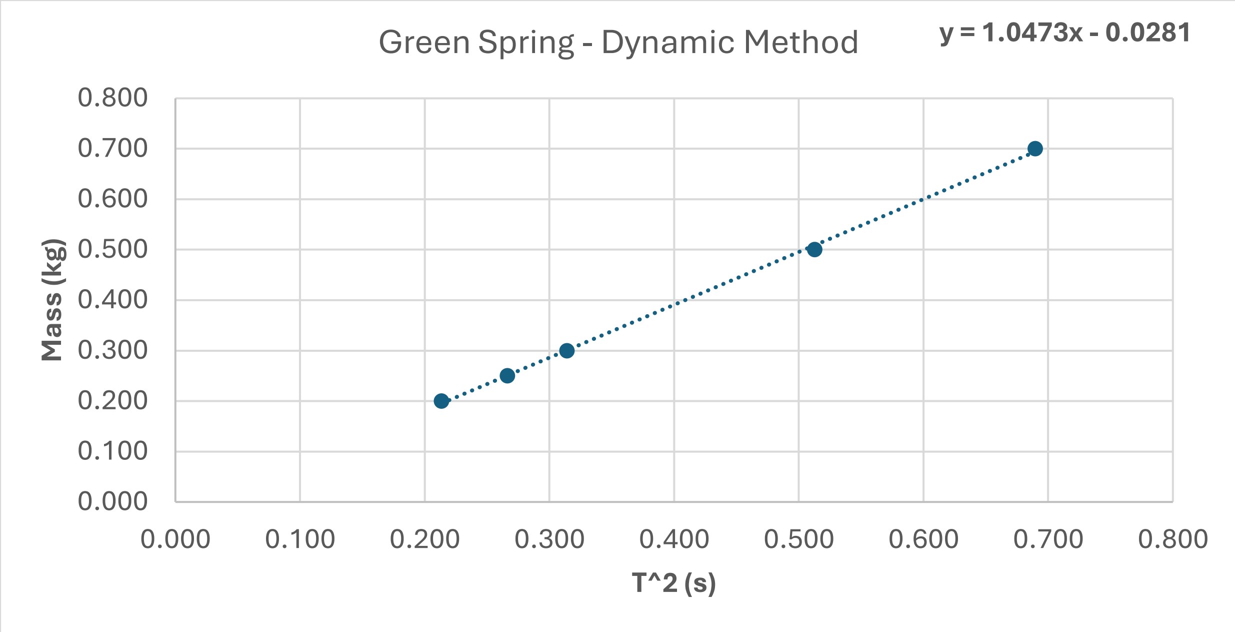
TABLE 2. *The table presents the standard values provided by the manufacturer alongside the experimentally obtained values for the green and blue springs. The low error indicate a strong agreement between the theoretical and experimental values, suggesting minimal experimental inaccuracies.*

Overall, the results validate Hooke's Law and confirm that the static method is a reliable approach to determining the stiffness of a spring.

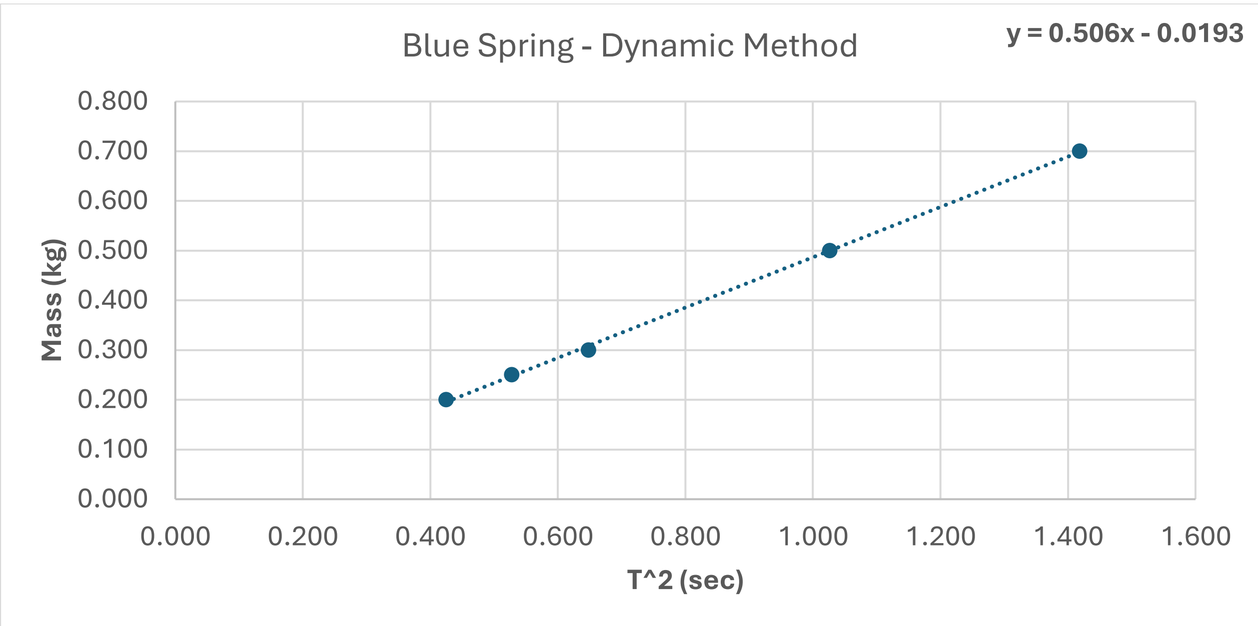
DYNAMIC METHOD

Dynamic Method					
Spring	Data point	m (kg)	Time for 10 Periods (s)	Period T (s)	T^2 (s)
Green	1	0.200	4.620	0.462	0.213
	2	0.250	5.160	0.516	0.266
	3	0.300	5.605	0.561	0.314
	4	0.500	7.160	0.716	0.513
	5	0.700	8.305	0.831	0.690
Blue	1	0.200	6.515	0.652	0.424
	2	0.250	7.265	0.727	0.528
	3	0.300	8.050	0.805	0.648
	4	0.500	10.130	1.013	1.026
	5	0.700	11.910	1.191	1.418

TABLE 3. *Summary of experimental data collected for the dynamic method. These values were used to determine the spring constant by plotting T^2 vs. mass and finding the slope in the graphs below.*



GRAPH 3. *This graph illustrates the relationship between period* (T^2) and mass (m). *The trendline equation y=1.0473x−0.0281 represents a linear fit, confirming the theoretical expectation that* ***mass*** *and* $\boldsymbol{T^2}$ *exhibit a* ***direct proportionality****. The positive slope indicates that as* ***mass increases****, the* ***oscillation period lengthens****, a characteristic feature of* ***simple harmonic motion.***



GRAPH 4. *This graph follows a similar pattern, with the equation y=0.506x−0.0193. The* ***lower slope*** *value compared to the green spring suggests that the* ***blue spring is less stiff****, aligning with its known lower spring constant. The* ***linearity*** *of the data points reinforces the validity of the simple harmonic motion model.*

Dynamic Method			
Spring	k Standart Value	k Experimental Value	Error
Green	40	41.346	3.36%
Blue	20	19.976	0.12%

TABLE 4. *This table presents the experimentally determined spring constants (k) using the dynamic method and compares them to the standard reference values. The green spring yielded an experimental spring constant of 41.346 N/m, with a 3.36% error relative to the expected value of 40 N/m. Similarly, the blue spring resulted in an experimental value of 19.976 N/m, with an exceptionally low 0.12% error compared to its standard value of 20 N/m.*

Despite these minor deviations, the results confirm the theoretical relationship between mass and oscillation period in simple harmonic motion, demonstrating the reliability of this approach in determining spring stiffness.

CONCLUSION

In this experiment, we determined the spring constants of green and blue springs using two independent methods: the static method, based on Hooke's Law, and the dynamic method, utilizing simple harmonic motion. The results showed that both methods provided spring constants that closely matched the standard values, with minor errors.

For the static method, the green and blue springs had experimental values of 40.271 N/m (0.68% error) and 19.736 N/m (1.32% error), respectively. The dynamic method yielded spring constants of 41.346 N/m (3.36% error) for the green spring and 19.976 N/m (0.12% error) for the blue spring. The low percentage errors in both methods confirm their reliability in determining the stiffness of a spring.

While both approaches produced accurate results, the **static method** demonstrated **slightly lower errors** due to its direct measurement of elongation under force. The dynamic method, though effective, was more **susceptible to timing inaccuracies** and damping effects **from air resistance.**

Potential sources of error include **human reaction time** in measuring oscillation periods, minor misalignments in displacement readings, and assumptions of negligible damping forces. To improve accuracy, future experiments could utilize high-speed motion sensors to measure displacement more precisely and automated timing systems to reduce human error in period measurement.

Overall, this experiment successfully demonstrated the validity of Hooke's Law and the relationship between oscillation period and spring stiffness, reinforcing fundamental principles of mechanics in elastic systems.

ACKNOWLEDGMENTS

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FIGURES

Tuiachieva, Z. (2025). Photo of the opened spring set box from the lab supplies [Figure 1].

Tuiachieva, Z. (2025). Photo of the front view of the opened spring set box from the lab supplies [Figure 2].

Tuiachieva, Z. (2025). Diagram illustrating the static method for determining the spring constant [Diagram 1].

Tuiachieva, Z. (2025). Photo of the spring stand from lab supplies [Figure 3].

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Tuiachieva, Z., & Villafan, J. (2025). Green spring - dynamic method [Graph 3].

Tuiachieva, Z., & Villafan, J. (2025). Blue spring - dynamic method [Graph 4].

TABLES

Tuiachieva, Z., & Villafan, J. (2025). Summary of elongation measurements of green and blue springs under different known weights [Table 1].

Tuiachieva, Z., & Villafan, J. (2025). Comparison of standard and experimental spring constant values for the green and blue springs [Table 2].

Tuiachieva, Z., & Villafan, J. (2025). Summary of experimental data collected for the dynamic method [Table 3].

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