Estimating the Spring Constant through Simple Harmonic Motion
PHYS 101

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1 Objective

To calculate k, the spring constant of a spring, using two methods:

1. *Static Method*: Measure the extension of the spring when various masses are added to find the spring constant.
2. *Dynamic Method*: Measure the period of simple harmonic motion for different added masses, and use a graphical technique to find the spring constant.

Instead of plugging the values we get directly into equations, we use a graphical technique which will give us a visual representation of the uncertainty and the linear graph.

2 Materials

- 2 $1m$ Metal Bars
- 1 Table and Bar Clamp
- 1 $90°$ Bar Clamp
- 1 Spring
- 1 Weight Holder (weighs $5g$ itself)
- Various weights ranging from $10g$ $50g$
- 1 Stopwatch

3 Procedure

Attach the table and bar clamp to the table and attach the bar. Attach the second bar to the first bar horizontally (to make a rod to which to attach the spring) using the 90 degree bar clamp. Place the spring on the horizontal rod and attach a mass on the bottom of the spring. For the *Static Method*, measure the length of the spring in equilibrium with the meter stick. For the *Dynamic Method*, measure the time period of some number of oscillations with the stopwatch. Write down the results and graph them using:

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

which can be converted into

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

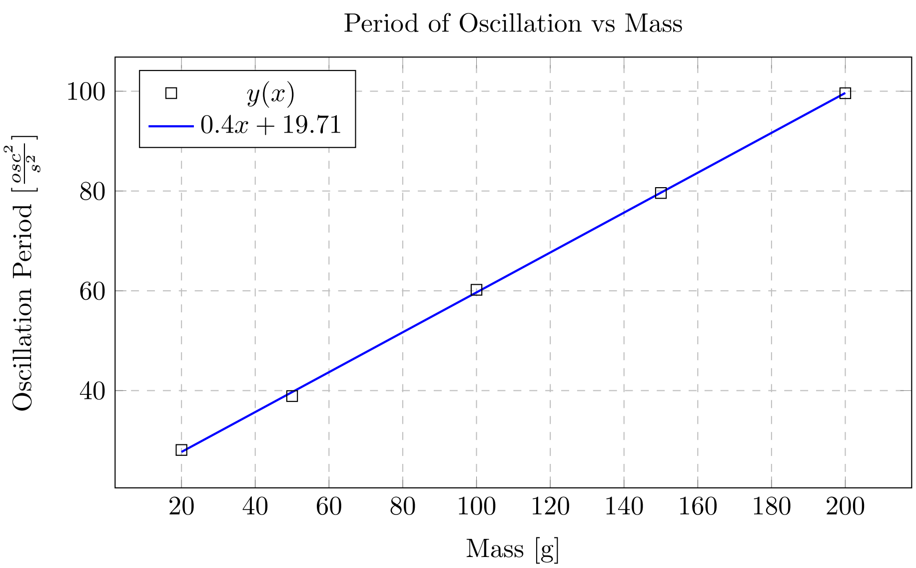
where $T = \frac{oscillations}{time}$.

This equation can be graphed with T on the y-axis and m on the x-axis such that the graph would have a slope of $\frac{2\pi}{k}$.

4 Experimental Data

After recording the *Static Method* and *Dynamic Method* with many different masses, we came to this set of data, where d_n represents the distance measured in the *Static Method* for the nth trial, in cm, and t_n represents the time measured in the *Dynamic Method* for the nth trial in s.

mass	d_1	d_2	d_3	d_4	d_5	d_{avg}	t_1	t_2	t_3	t_4	t_5	t_{avg}
20g	23.5	25	23.75	23.7	24.1	24.01	5.29	5.37	5.28	5.25	5.32	5.30
50g	27	26.5	26.7	27.2	26.9	26.86	6.32	6.15	6.29	6.25	6.18	6.24
100g	32.7	32.4	33.3	32.9	33.3	32.92	7.72	7.72	7.75	7.78	7.84	7.76
150g	39	39.1	39.3	39.4	39.4	39.24	8.71	8.94	9.00	8.93	9.03	8.92
200g	45.3	45.2	45.7	45.6	45.5	45.46	10.00	9.94	10.00	9.91	10.06	9.98

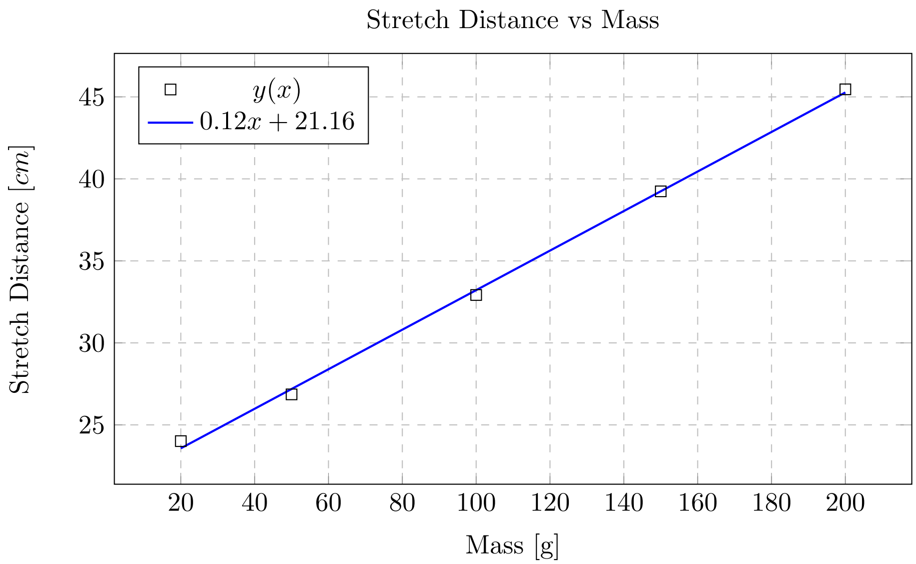


We can then estimate k with the slope of this graph.[1]

$$0.4 = \frac{2\pi}{k}$$
$$k = \frac{2\pi}{0.4}$$
$$k = 15.7$$

[1]This value clashes with the value found by mathematically solving for k, likely due to an error in the graph.

We can also estimate k by looking at a graph of stretch distance vs mass.



We can then estimate k with the *inverse* of the slope of this graph.

$$k = \frac{1}{0.12}$$
$$k = 8.\overline{3}$$

5 Results and Conclusions

We ran the necessary calculations on $200g$ ($0.2kg$) masses for our final answer, but the provided graphs scale linearly. Using the *Static Method*:

$$
\begin{aligned}
F &= kx \\
(0.2m)(9.8\frac{m}{s^2}) &= k(0.45m - 0.21m) \\
k &= \frac{(0.2m)(9.8\frac{m}{s^2})}{0.24m} \\
k &= 8.06\frac{N}{m}
\end{aligned}
$$

we estimated the spring to have a spring constant of $8.06\frac{N}{m}$. Using the *Dynamic Method* where T is the period of oscillation:

$$
\begin{aligned}
T^2 &= \frac{2\pi^2}{k}m \\
\frac{10}{10.0}\frac{osc}{s}^2 &= \frac{2\pi^2}{k}(0.2kg) \\
1.0 &= \frac{(2\pi)^2}{k}(0.2kg) \\
k &= 2\pi^2(0.2g) \\
k &= 7.895\frac{N}{m}
\end{aligned}
$$

the estimate becomes $7.895\frac{N}{m}$. The two forms of estimation agreed with each other to within ± 0.165.