Lab 4: Hooke's Law

Name: **Your Name**
Class: **PHYS 2125 (15921)**
Date: **2025-02-07**

- [ ] TODO: final edits

Objective

To determine the spring constant of a string, and then the mass of an unknown weight, using Hooke's law.

Equipment

- (1) small A-base
- (1) long metal rod
- (1) clamp
- (1) short rod
- (1) spring set
  - (1) "medium strength" spring with unknown k value
  - (1) 5g hook
- (1) set of weights with known masses
- (1) weight of unknown mass
- (1) 1 meter ruler

Theory

The downward force of a weight, F_a, can be calculated per the equation

$$F_a = M_H g$$

where M_H is the mass of the weight and g is the gravitational constant of the Earth.

This force can also be calculated per the equation

$$F_a = kx$$

where k is the spring constant of the spring in question and x is the amount of elongation of the spring.

Because of Newton's third law we know that the force exerted on the spring, F_s is the opposite of F_a, such that $F_s = -F_a$.

Together can be rewritten as *Hooke's law*:

$$F_s = -kx$$

We can leverage these two relationships to derive a third, allowing us to relate the mass of a weight, M_H, directly to the spring constant, k.

$$M_H g = kx$$

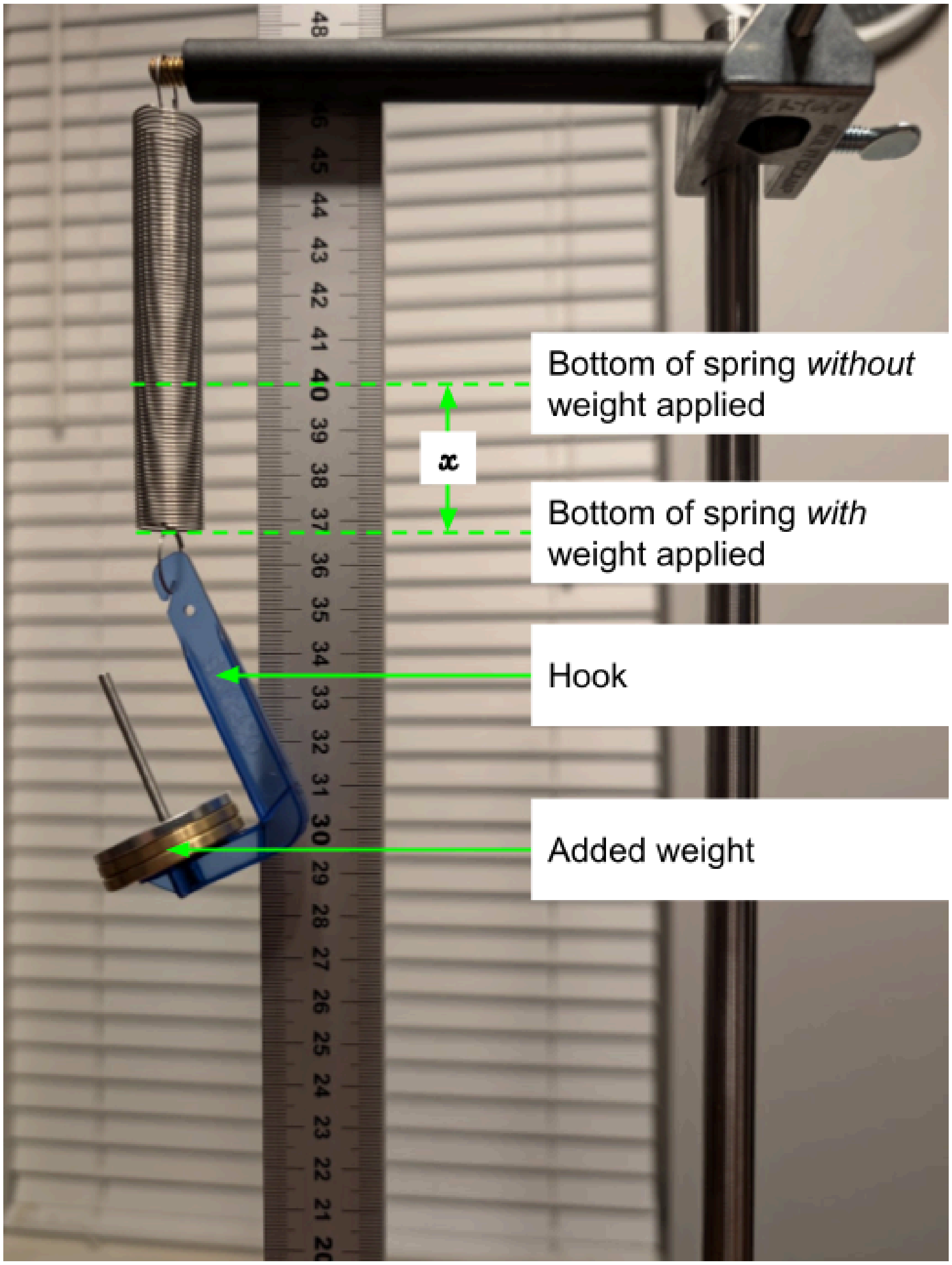
In a two step process we will use weights of a known mass and a spring of an unknown k value to calculate the mass of a weight of unknown mass.

1. By using a variety of different weights of known mass we will determine the spring constant, k of the spring we are using.
2. With k determined we will then use Hooke's law to to determine the mass of the unknown weight.

Note: we are using a 5g hook to suspend the weights, and as such M_H will be calculated per

$$M_H = M_h + M_a$$

where M_h is the 5g mass of the hook and M_a is the weight of the mass added in that trial.


Bottom of spring *without* weight applied
x
Bottom of spring *with* weight applied
Hook
Added weight

Procedure

The following procedure was followed.

Initial Setup

The pendulum was constructed as follows.

1. A small cast iron A-base was placed on the table.
2. A 45cm steel rod was secured into the A-frame, raised up as much as possible to maximize the height.
3. The vertical mounting side of a steel clamp was secured at the very top of the rod.
4. A 15cm rod was attached to the horizontal side of the same steel clamp, to the far end of the smaller rod.
5. A spring with an unknown k value was supsended from the small rod, opposite the clamp.

Trial (completed for each M_a)

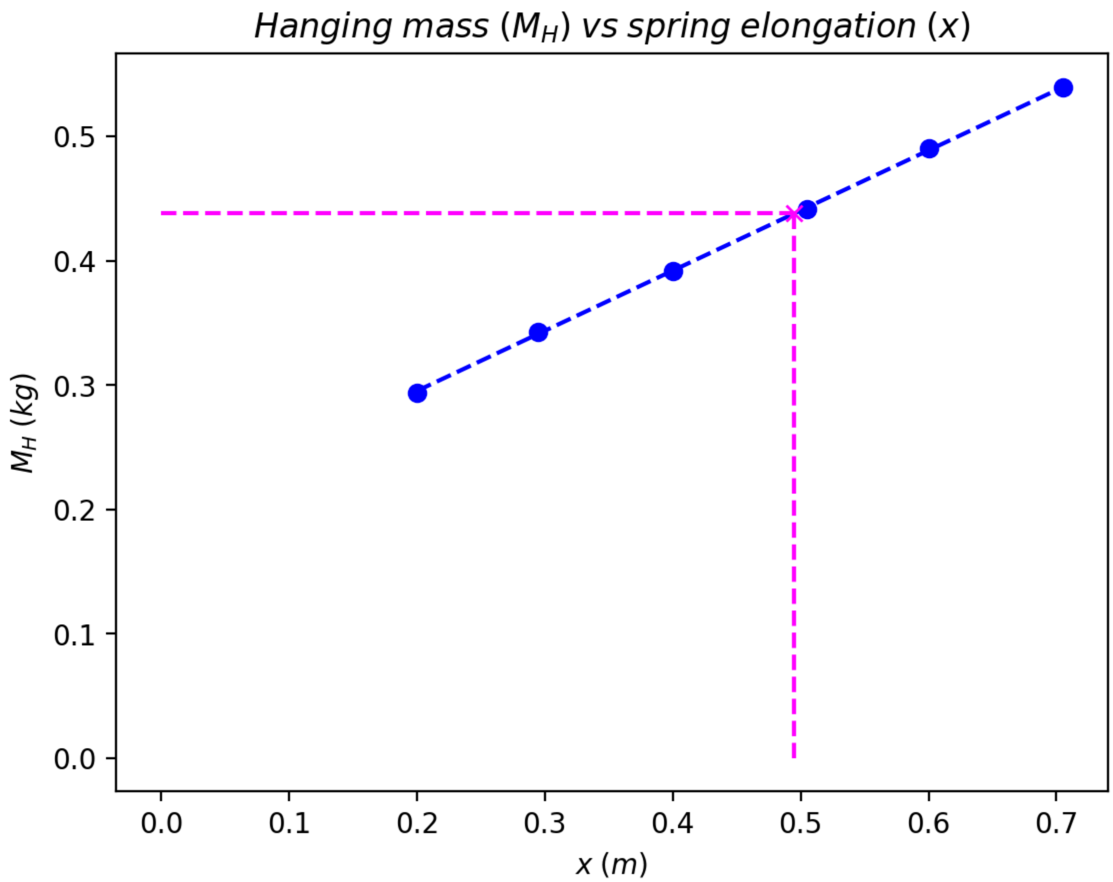
Each measurement was conducted twice and measured as x_1 and x_2.

1. A 25g weight was attached to the hook, and x was recorded.
2. Weight was increased in 5g increments through 50g, with x recorded for each.
3. The weight of unknown mass was placed on the hook, and again the elongation, x was measured.

Data

M_a (kg)	M_h (kg)	M_H (kg)	M_H g (N)	x_1 (m)	x_2 (m)	x_{avg} (m)	k (N/m)
0.025	0.005	0.03	0.294	0.21	0.19	0.200	1.47
0.03	0.005	0.035	0.343	0.31	0.28	0.295	1.162712
0.035	0.005	0.04	0.392	0.41	0.39	0.400	0.98
0.04	0.005	0.045	0.441	0.51	0.50	0.505	0.873267
0.045	0.005	0.05	0.49	0.61	0.59	0.600	0.816667
0.05	0.005	0.055	0.539	0.71	0.70	0.705	0.764539
M_Unknown	0.005			0.50	0.49	0.495	

Calculations



Using the least squares method a trend line is fit to the data with *slope* 0.48 and y*-intercept* 0.20, resulting in the equation $y = 0.48x + 0.20$.

The spring elongation for the unkown mass was then plotted on this trendline at $(0.495, 0.438)$, as shown in magenta.

Results

The value of k was determined using the mean, k_t, and the least squares fit, k_g.

$k_t = 1.011\ N/m$

$k_g = 0.484\ N/m$

This equates to a 70.58% difference.

These mass of the unknown weight was then calculated as M_t and M_g using k_t and k_g respectively.

$M_t = (1.011 * 0.495)/9.8 - 0.05 = 0.0461\ kg$

$M_g = (0.438/9.8) - 0.005 = 0.0397\ kg$

This equates to a 14.92% difference.

Discussion

Explain the two reasons for not getting % difference close to zero. (3 pts)

Question 1 Answer

What was the most difficult measurement to make during this experiment? (3 pts)

Question 2 Answer

Why did you take two x-values for each mass? (4 pts)

Question 4 Answer