# Physics 1D03: Lab 2

HOOKE'S LAW

Updated: Apr. 29, 2024

## Lab Objectives

- Understand the theory behind Hooke's Law and the physics behind springs.
- Experimentally determine a spring constant through Hooke's Law, Conservation of Energy, and measuring period.
- Learn more about Excel and calculating functions.
- Justify the spring constant and springs mass with theoretical predictions.
- Working with uncertainties when recording measurements.

## Equipment



Spring-Mass system



Stop-Watch

Goal is to first find the spring constant, k, and noload position of the spring,  $x_0$ 

 Place the metal pan (*without any additional masses*) on the spring

Refer to image for an example of the set-up

 Using the ruler, measure the position of the bottom edge of the pan





- After taking the measurement, add a 20gm mass to the pan and record the new position (include an uncertainty measurement)
  - Note: Do <u>not</u> measure the difference of position, just record only the values you see on the ruler
  - Record this value in your report

 Add another 20gm mass and repeat the above steps until you have a total of 10 measurements



•We can now use Excel to plot our results

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| Mass (kg) Mass | uncertai                | inty ( kg | ) Load ( | ( kg*m/s/ | ^2)  | Load Un | certaint | y (kg*n | 1/s^2 | Pan Position (m) |          |          |         |          |
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| Mass (kg) | Mass Uncertainty ( kg) | Load ( kg*m/s^2) | Load Uncertainty (kg*m/s^2 | Pan Position (m)      |            |
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|           | 0                      | 0                | 0                          |                       |            |
|           | 0                      | 0                | 0                          |                       |            |
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|           | 0.5                    |                  |                            |                       |            |
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|           | 0.1                    |                  |                            |                       |            |
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9

Copy data from Excel sheet into your lab report

 Generate a line of best fit on your Excel graph and use that to find the spring constant, k, and no-load position of the spring, x<sub>0</sub>

- Hint: Consider how your line of best fit is related to Hooke's Law  $F = k \Delta x$ 

where  $\Delta x$  is the displacement from the no-load position. What would *F* be in this case?



 We now want to measure the potential energy of the spring using the displacement of the mass

 Energy conservation tells us that the energy before/after the mass is dropped is given by

$$mgh = \frac{1}{2}kx^2$$

which can be rewritten as

 $\log(mh) = 2 \log(h) + \text{constant}$ 

This equation is what we will use to test energy conservation

- Start by moving the empty pan up to the no-load position, x<sub>0</sub>, measured from Part 1
- Place the paper slider directly below the pan and record its position in the report
- Release the pan, allowing the slider be pushed down
  - Record the mass of the pan and new slider <u>position (not the displacement)</u> in your report and Excel file
- Repeat the above steps 5-6 more times, adding an additional 20gm to the pan each time
- •We can now use the data to plot log(*mh*) *vs*. log(h)



| Uncertainty in height (m) = | -                        | <- record uncertainty in B1 |                        |            |                           |                |                               |  |
|-----------------------------|--------------------------|-----------------------------|------------------------|------------|---------------------------|----------------|-------------------------------|--|
| xo (m) =                    |                          | <- record xo in B2          |                        |            |                           |                |                               |  |
|                             |                          |                             |                        |            |                           |                |                               |  |
| Mass (kg)                   | Uncertainty in mass (kg) | Position of paper (m)       | Change in height h (m) | log(h) (m) | Uncertainty in log(h) (m) | log(mh) (kg*m) | Uncertainty in log(mh) (kg*m) |  |
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| Uncertainty in height (m) = | =                        | <- record uncertainty in B1 |                        |            |                           |                |                               |  |
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| xo (m) =                    |                          | <- record xo in B2          |                        |            |                           |                |                               |  |
|                             |                          |                             |                        |            |                           |                |                               |  |
| Mass (kg)                   | Uncertainty in mass (kg) | Position of paper (m)       | Change in height h (m) | log(h) (m) | Uncertainty in log(h) (m) | log(mh) (kg*m) | Uncertainty in log(mh) (kg*m) |  |
|                             | C                        |                             | 0                      | #NUM!      | #DIV/0!                   | #NUM!          | #DIV/0!                       |  |
|                             | C                        |                             | 0                      | #NUM!      | #DIV/0!                   | #NUM!          | #DIV/0!                       |  |
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| Uncertainty in height (m) | icertainty in height (m) = |                       |                        |            |             |               |                |                              |    |
|---------------------------|----------------------------|-----------------------|------------------------|------------|-------------|---------------|----------------|------------------------------|----|
| xo (m) =                  |                            | <- record xo in B2    |                        |            |             |               |                |                              |    |
|                           |                            |                       |                        |            |             |               |                |                              |    |
| Mass (kg)                 | Uncertainty in mass (kg)   | Position of paper (m) | Change in height h (m) | log(h) (m) | Uncertainty | in log(h) (m) | log(mh) (kg*m) | Uncertainty in log(mh) (kg*m | 1) |
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| Uncertainty in height (n | ı) =                     | <- record uncertainty in B1   |                        |            |                                      |   |                                       |  |
|--------------------------|--------------------------|---|------------------------|------------|--------------------------------------|---|---------------------------------------|--|
| xo (m) =                 |                          | <- record xo in B2  |                        |            |                                      |   |                                       |  |
|                          |                          |   |                        |            |                                      |   |                                       |  |
| Mass (kg)                | Uncertainty in mass (kg) | Position of paper (m)   | Change in height h (m) | log(h) (m) | Uncertainty in log(h) (m)            | log(mh) (kg*m)  | Uncertainty in log(mh) (kg*m)         |  |
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Here we want to measure the "effective spring mass", m<sub>0</sub>

Starting with 50gm mass, drop the pan from an initial starting position

Record the time it takes to complete 50 oscillationsRecord this value in your Excel file/report

Repeat 4 more times using 60gm, 70gm, 90gm, and 110gm masses

•We can now use Excel to plot the mass as a function of  $T^2$ 

| Uncertainty of time (s) | Number of swings n         | Error in Period (s)    |             |                       |                                |  |
|-------------------------|----------------------------|------------------------|-------------|-----------------------|--------------------------------|--|
|                         | 50                         | 0                      |             |                       |                                |  |
|                         |                            |                        |             |                       |                                |  |
|                         |                            |                        |             |                       |                                |  |
| Mass (kg)               | Uncertainty in mass ( kg ) | Time for 50 swings (s) | Period (s)  | Period squared ( s^2) | Error in Period Squared ( s^2) |  |
|                         | 0                          |                        | 0.000       | 0.000                 | 0.000                          |  |
|                         | 0                          |                        | 0.000       | 0.000                 | 0.000                          |  |
|                         | 0                          |                        | 0.000       | 0.000                 | 0.000                          |  |
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| Uncertainty of time (s) | Number of swings n       | Error in Period (s)        |             |                       |                             |                |
|-------------------------|--------------------------|----------------------------|-------------|-----------------------|-----------------------------|----------------|
|                         | 50                       | ) 0                        |             |                       |                             |                |
|                         |                          |                            | -           |                       |                             |                |
|                         |                          |                            |             |                       |                             |                |
| Mass (kg)               | Uncertainty in mass ( kg | ) Time for 50 swings ( s ) | Period (s)  | Period squared ( s^2) | Error in Period Squared ( s | <sup>2</sup> ) |
|                         | (                        |                            | 0.000       | 0.000                 | 0.000                       |                |
|                         | (                        |                            | 0.000       | 0.000                 | 0.000                       |                |
|                         | (                        | /                          | 0.000       | 0.000                 | 0.000                       |                |
|                         | (                        |                            | 0.000       | 0.000                 | 0.000                       |                |
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|                         | 0.8                      |                            |             |                       |                             |                |
|                         | 0.6                      |                            |             |                       |                             |                |
|                         | 0.0                      |                            |             | Resul                 | ts will automatically b     | be line        |
|                         | 0.4                      |                            |             |                       | calculated here             |                |
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|                         | 0.000 0.200              | 0.400 0.600                | 0.800 1.000 |                       |                             |                |
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|                         |                          |                            |             |                       |                             |                |
|                         |                          |                            |             |                       |                             |                |

| Mass (kg)       Uncertainty in mass (kg)       Time for 50 swings (s)       Period (s)       Period squared (s^2)       Error in Period Squared (s^2)         0       0       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0       0       0       0       0         0       0       0       0       0       0       0         0       0       0       0       0       0       0       0         0       0       0 <th>Uncertainty of time (s)</th> <th>Number of swings n</th> <th>Error in Period (s)</th> <th></th> <th></th> <th></th> <th></th>  | Uncertainty of time (s) | Number of swings n       | Error in Period (s)      |             |                      |                              |    |
|--|-------------------------|--------------------------|--------------------------|-------------|----------------------|------------------------------|----|
| Mass ( kg )       Uncertainty in mass (kg )       Time for 50 swings (s )       Period ( s )       Period squared ( s^2)       Error in Period Squared ( s^2)       Image: constrainty in mass (kg )       Constrainty in mass (kg )       Time for 50 swings (s )       Period ( s )       Period squared ( s^2)       Error in Period Squared ( s^2)       Image: constrainty in mass (kg )       Image: constrait (kg )       Image: constrait (kg )  |                         | 50                       | ) 0                      |             |                      |                              |    |
| Mass ( kg)       Uncertainty in mass (kg)       Time for 50 swings (s)       Period ( s)       Period squared ( s^2)       Error in Period Squared ( s^2)       Image: constrainty in mass ( kg)         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0       0.000       0.000       0.000       0.000       0.000         0.8       0       0       0       0       0       0       0       0       0       0         0.8       0       0       0       0       0       0       0       0       0       0       0       0       0       0 <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>   |                         |                          |                          |             |                      |                              |    |
| Mass (kg)       Uncertainty in mass (kg)       Time for 50 swings (s)       Period (s)       Period squared (s^2)       Error in Period Squared (s^2)         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         0       0       0       0.000       0.000       0.000       0.000         0       0       0.000       0.000       0.000       0.000       0.000         1       0       0       0       0       0       0       0         0       0       0       0       0       0       0       0       0         0       0       0       0       0       0       0       0       0       0       0       0  |                         |                          |                          |             |                      |                              |    |
| 0       0.000       0.000       0.000         0       0.000       <  | Mass (kg)               | Uncertainty in mass ( kg | ) Time for 50 swings (s) | Period (s)  | Period squared (s^2) | Error in Period Squared ( s' | 2) |
| 0       0       0.000       0.000       0.000         0       0       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         12       0       0       0       0.000       0.000         13       0.000       0.000       0.000       0.000       0.000         0.000       0.000       0.000       0.000       0.000       0.000         0.000       0.000       0.000       0.000       0.000       0.000         0.000       0.000       0.000       0.000       0.000       0.000       0.000         0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000  |                         | 0                        |                          | 0.000       | 0.000                | 0.000                        |    |
| 0        |                         | 0                        |                          | 0.000       | 0.000                | 0.000                        |    |
| 0       0.000       0.000       0.000       0.000         0       0.000       0.000       0.000       0.000         12       1       1       1       1         13       1       1       1       1         14       1       1       1       1         10       1       1       1       1         14       1       1       1       1         15       1       1       1       1         10       1       1       1       1         15       1       1       1       1         16       1       1       1       1         10       1       1       1       1         10       1       1       1       1         10       1       1       1       1         10       1       1       1       1       1         10       1       1       1       1       1       1         10       1       1       1       1       1       1       1         10       1       1       1       1       1  |                         | 0                        |                          | 0.000       | 0.000                | 0.000                        |    |
| Chart Title  Chart Title  Chart Title  Plot for 'Mass' vs. 'Period^2' appears here (Remember to label/rescale)  Out Out Out Out Out Out Out Out Out Ou   |                         |                          |                          | 0.000       | 0.000                | 0.000                        |    |
| Chart Title  Chart |                         | l l                      | ,                        | 0.000       | 0.000                | 0.000                        |    |
| Chart Title  |                         |                          |                          |             |                      |                              |    |
| 12   1   1   1   0.8   0.6   0.4   0.2   0.00   0.20   |                         |                          | Chart Title              |             |                      |                              |    |
| Plot for 'Mass' vs. 'Period^2'<br>appears here<br>(Remember to label/rescale)  |                         | 1.2                      |                          |             |                      |                              |    |
| Plot for 'Mass' vs. 'Period^2'<br>appears here<br>(Remember to label/rescale)  |                         |                          |                          |             |                      |                              |    |
| 08 appears here   0.6  |                         | 1                        |                          |             | Plot for 'N          | /lass' vs. 'Period^2'        |    |
| 0.6       0.6       0.4       0  |                         | 0.8                      |                          |             | ar                   | ppears here                  |    |
| 0.6 0.4   0.2   0   0.000   0.200   0.40   0.600   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   0.800   1.000   1.000   0.800   1.0   |                         |                          |                          |             | (Pomomb              | ,<br>or to label/rescale)    |    |
| 0.4   0.4   0.20   0.400   0.800   1.000   |                         | 0.6                      |                          |             | (Kenieniu            | er to label/rescale)         |    |
|  |                         | 0.4                      |                          |             |                      |                              |    |
|  |                         | 0.4                      |                          |             |                      |                              |    |
|  |                         | 0.2                      |                          |             |                      |                              |    |
|  |                         |                          |                          |             |                      |                              |    |
|  |                         | 0 0 0 200                | 0.400 0.600              | 0.800 1.000 |                      |                              |    |
|  |                         | 0.000 0.200              |                          | 1.000       |                      |                              |    |
|  |                         |                          |                          |             |                      |                              |    |
|  |                         |                          |                          |             |                      |                              |    |

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Copy data from Excel sheet into your lab report

-Generate a line of best fit on your Excel graph and use that to find the effective spring mass,  $m_0$ 

• Hint: Since you are plotting m vs.  $T^2$ , compare your line of best fit to the equation

$$m = -m_0 + \frac{kT^2}{4\pi^2}$$

## Good Luck!