SHM by motion sensor

Apparatus

Motion sensor.

Retort stand boss and clamps.

G clamp.

Soft spring - section of a slinky (see practical notes)

Mass carrier and masses

Light weight "target"

Protection for the sensor

Data recording setup.

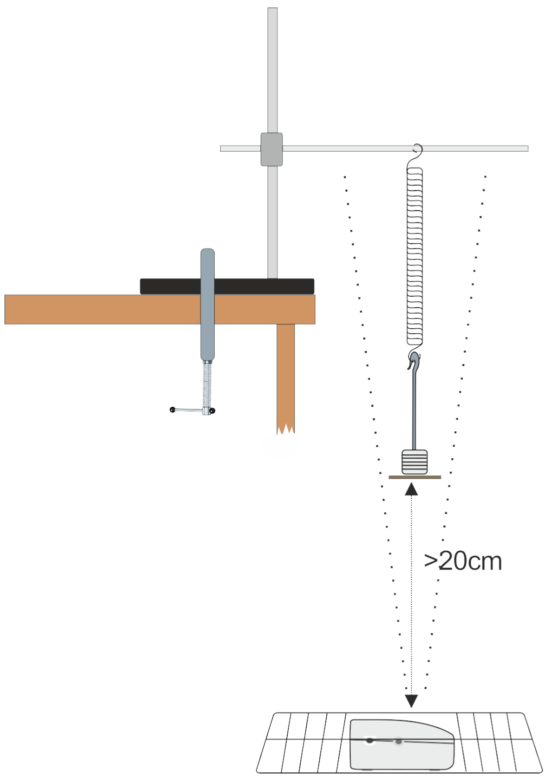
Single pane layout, graph.

Settings

30 second recording

Intersample time 10ms

Select Start to begin, stop after 30 seconds



Vibrations play a very important part in our lives. The effects can be beneficial or destructive. Here are a few examples:-

- Vibration induced motion sickness.
- Listening to music with a CD player or at a concert.
- Earthquakes.
- Clocks.
- In car engines.
- Spring-mass systems.

Any motion that repeats itself is described as **harmonic motion.** We will be investigating a particular form of harmonic motion known as **simple harmonic motion (SHM).**

In this investigation you are going to seek answers to the following questions:-

1. How does the distance (displacement) from the centre of oscillation change during each cycle?
2. What is the phase relationships between the:-
   - Displacement - **x**
   - Velocity – **v**
   - Acceleration – **a**
3. How closely does the oscillation of a spring relate to SHM?

   T = period of the oscillation in seconds.

   ω = angular velocity of the SHM in radians sec^{-1}.

Preliminary questions

1. Draw a sketch graph showing how you expect the displacement to change with time during two oscillations of the spring.
2. Make a copy of your sketch from question 1 and add to it curves showing how you expect the velocity and acceleration of the object will change during those two oscillations.

Method

- Set up the apparatus as shown in the diagram. Check the oscillation of the suspended mass does not drop below 17 cm (the lower limit of the motion sensor range).
- Connect the sensor to the software, change the measurement range to 1.5m.
- Change the intersample time to 20ms or 10ms.
- Start the data collection and without touching or moving the mass, use the tare function to set the resting position of the data as Zero - this will mean that changes in distance will now be displacement about the zero.
- Pull the mass down and set it oscillating, start the data recording and stop after you have collected no more than 10 peaks.
- Check the data is smooth and if necessary alter the position of mass, sensor and repeat. Use the Run manager to remove any unwanted data sets.
- Save the data

Results and analysis.

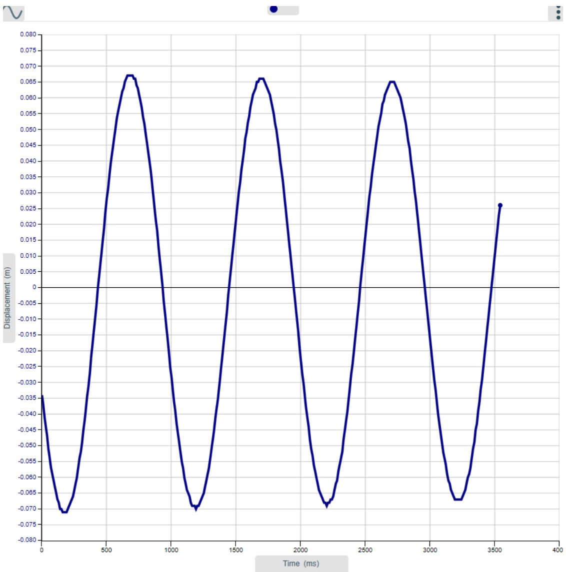
Mass of spring and load =   Kg.

The data as collected will show change in displacement (assuming you used the tare function to set zero).

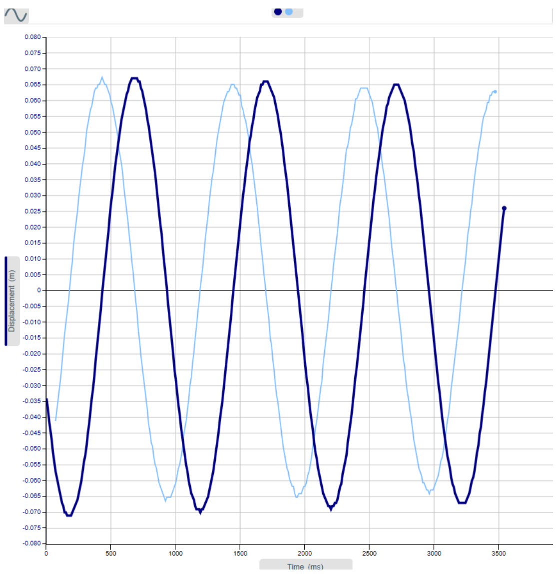
Use the calculation formula dx/dt to create a time velocity curve from the displacement data.

Use the calculation formula dx/dt to create a time acceleration curve from the velocity data.

Use separate axis for Displacement, velocity and acceleration and use scale min to max to create and overlay of all the functions.



Example of data as collected, rescaled to min to max



Same data, with velocity

To produce Velocity from displacement.

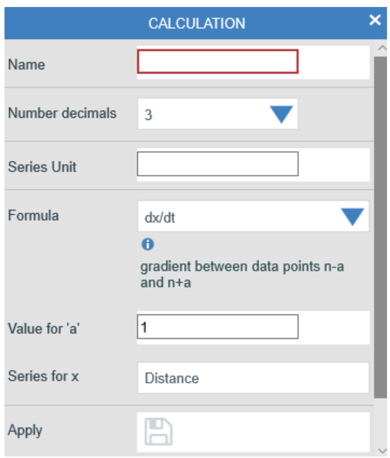
Select the calculate tool.

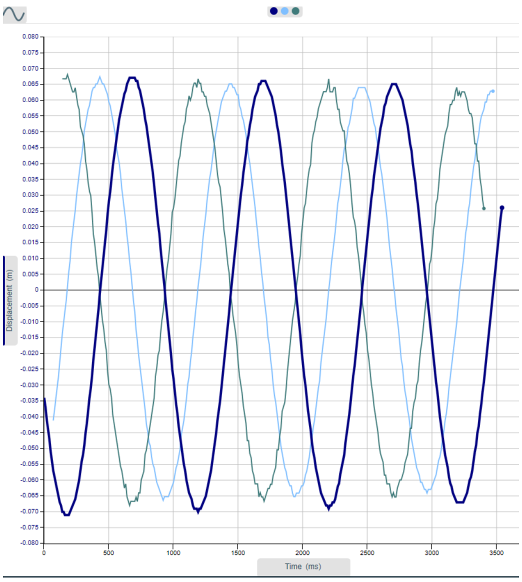
Scroll down the formula list and select dx/dt

Set name to Velocity, number of decimals to 4, series unit to m/s, value for a to 7.

The value for a is the number of points the derivative gradient is taken, it smooths the result.

The settings may need to be altered to match your collected data.





Data with Displacement, velocity and acceleration plotted.

B) Analysing the results

1. Phase Relationships

Compare the velocity and acceleration curves, with the displacement curve. Are they ‘in phase’ or out of phase with the displacement curve? If they are out of phase say by how much (¼ or ½ of an oscillation i.e. $\pi/4$ or $\pi/2$)?

Curve	In phase or phase difference
Velocity	
Acceleration	

2. Comparing the graphs.

Using **Zoom,** display one whole cycle of the displacement graph. Fill in the following table. State the value of the displacement (choose from: maximum positive, maximum negative or zero) for the positions in the velocity and acceleration graphs, shown in the table.

Position in v, a graphs	Corresponding position in the displacement graph
Velocity is zero	
Velocity is at maximum positive	
Acceleration is at maximum negative	
Acceleration is at maximum positive	

3. Calculation of the Period and ω.

a) Calculate the Period from the graph.

b) Calculate the angular velocity ω from the equation: -

$$T = \frac{2\pi}{\omega}$$

Questions

1. If $x = -A\sin\omega t$, what is the value of $\sin \omega t$ when the displacement is maximum?
2. If $v = -A\omega\cos\omega t$, what is the value of $\cos \omega t$ when the value of the velocity is a maximum?
3. A small mass attached to a spring oscillates in simple harmonic motion with amplitude of 50 mm. It takes 30 seconds to complete 10 oscillations. Calculate its period, angular velocity, maximum speed and the maximum acceleration.

Extension.

Use alternative plots of displacement against velocity and acceleration, also known as phase space diagrams.

Explain what the phase space diagram for an oscillator shows.

Investigate the effect of change in mass and or spring length has on oscillation period and amplitude.

Attach a card to the base of the mass

How does the phase space diagram for a damped oscillation compare to the one for an undamped oscillation.