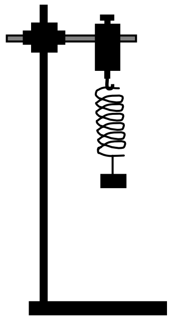
A MASS ON A SPRING

Car suspension consists of two basic components: springs and shock absorbers. A coil-over-oil unit is an all-in-one system that carries both the spring and the shock absorber. The adjustable spring plate can be used to make the springs stiffer and looser, whilst the adjustable damping valve can be used to adjust the rebound damping of the shocks.

- How does the force exerted by an elastic spring change with time during vertical oscillations of a mass attached to the spring?
- How does the period of oscillations depend on the mass attached to the spring?
- Try to find a mathematical model of simple harmonic motion

A. Preparation



1) What are the forces acting on the hanging mass in the picture on the right? Draw a free-body diagram for the spring-mass system.
2) Do you expect a change of force, when you pull the mass down?
3) What will happen to the force, when you release the mass after pulling it down?

B. Observation of an experiment

Preliminary experiments:

1) First, without connecting the force sensor or the motion detector to the calculator, pull the mass down slightly, release it and observe the oscillations. Make a sketch respectively for a distance vs. time graph, for a velocity vs. time graphs, and finally, for an acceleration vs. time graph. Accordingly, use the same axis for time.

2) Connect the interface to your handheld or computer, activate the sensor and start the experiment by pulling the mass slightly down and then releasing it. Display the shape of the graph. What is the meaning of a positive force on this graph? What is the meaning of a negative force?

3) Describe the motion of the mass, when the force has its maximum and minimum values as well as its zero values. In which direction does the mass move in each instance? How is the slope of the curve related to the motion of the mass?

C. Modeling the situation in the laboratory

1) What is the period of oscillations? What mass is attached to the spring?

2) What will happen to the period of oscillations if you increase the mass attached to the spring?

3) Record different masses and periods you measured in a table and find a mathematical model. Explain, what mathematical model you use to best fit these data?

4) Investigate the influence of damping the mass-spring system. What is going to be influenced?

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5) *Extension1:* Deliberate with your group members what other factors could influence the period of oscillations and, if possible, make same further experimental runs.

6) *Extension2:* Compare the observed motion of a spring-mass system to a mathematical model of simple harmonic oscillation.

D. Evaluating the data obtained

1) View the graphs of the last run on the calculator. Compare the position vs. time and the velocity vs. time graphs. How are they the same? How are they different?

2) Trace across the velocity graph to view the data values. Record in a table, a time when the velocity is greatest and another time when the velocity is zero. Then, switch to the distance graph and trace to the same two times. Relative to the equilibrium position, where is the mass, when the velocity is zero? Where is the mass, when the velocity is greatest?

3) Does the frequency appear to depend on the amplitude of the motion? Do you have enough data to draw a firm conclusion?

4) Does the frequency appear to depend on mass used? Did it change much in your tests?

5) Does damping change the data?

6) *Extension 1*: Investigate, if possible, how changing the spring constant changes the period of motion.

7) *Extension 2*: Compare your experimental data to the sinusoidal function model using the following equation: $y = A \sin(2\pi ft + \varphi) + y_0$ where y_0 represents the equilibrium distance.

E. Show your results

Thinking about your observations, discuss the correctness of the following statements:

a) When the velocity has the largest magnitude, the mass is passing through the equilibrium position and the net force acting on the mass has also the largest magnitude.

b) When the velocity is zero, the mass is at a maximum or minimum position.

c) The frequency is bigger for larger mass.

d) When the velocity is zero, there is not net force acting on the mass.

e) If m is doubled, the system will complete twice as many cycles in the same time.