PHYSICS EXPERIMENT

Elliptical Oscillation of a String Pendulum

DESCRIPTION OF ELLIPTICAL OSCILLATIONS OF A STRING PENDULUM AS THE SUPERIMPOSITION OF TWO COMPONENTS PERPENDICULAR TO ONE ANOTHER.

- Plot the elliptical oscillation of a string pendulum in the form of two perpendicular components for a variety of initial conditions.
- Distinguish between the special cases when the oscillation is in a plane which bisects the alignments of the two sensors, when the oscillation is perpendicular to the aforementioned plane and when the oscillation is circular.

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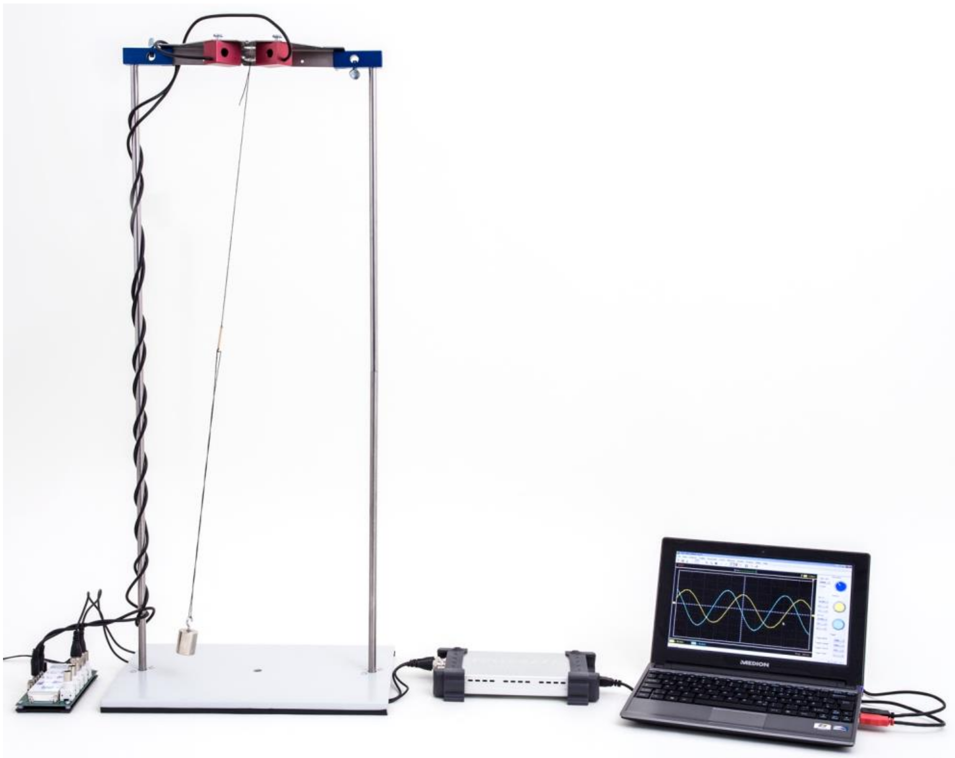

Fig. 1: Experiment set-up

GENERAL PRINCIPLES

Depending on the initial conditions, a suitable suspended string pendulum will oscillate in such a way that the bob's motion describes an ellipse for small pendulum deflections. If the motion is resolved into two perpendicular components, there will be a phase difference between those components.

This experiment will investigate the relationship by measuring the oscillations with the help of two perpendicularly mounted dynamic force sensors. The amplitude of the components and their phase difference will then be evaluated. The phase shift between the oscillations will be shown directly by displaying the oscillations on a dual-channel oscilloscope.

Three special cases shed light on the situation:

a) If the pendulum swings along the line bisecting the two force sensors, the phase shift φ = 0°.

b) If the pendulum swings along a line perpendicular to that bisecting the two force sensors, the phase shift φ = 180°.

c) If the pendulum bob moves in a circle, the phase shift φ = 90°.

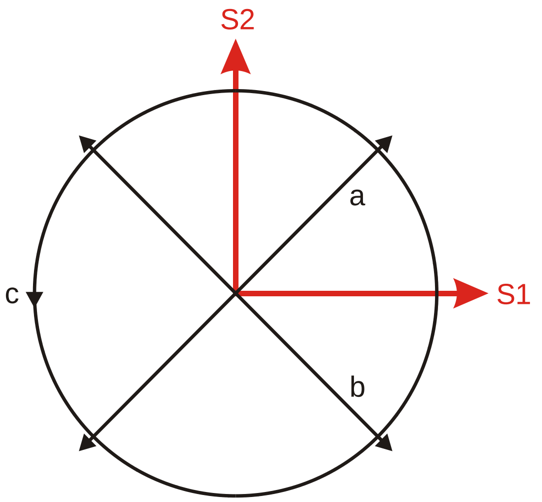

Fig. 2: The alignment of sensors S1 and S2, including the oscillation directions of the string pendulum under investigation

LIST OF EQUIPMENT

1	SW String Pendulum Set	1012854 (U61025)
1	SW Stand Equipment Set	1012849 (U61022)
1	SW Sensors Set @230 V	1012850 (U61023-230)
or		
1	SW Sensors Set (@115 V	1012851 (U61023-115)
1	USB Oscilloscope 2x50 MHz	1017264 (U112491)

SET-UP

- Screw the stand rods with both external and internal threads into the outer threaded sockets of the base plate.
- Extend both rods by screwing rods with external thread only onto the ends of them.
- Attach double clamps near the top of both stand rods and turn them to point inwards so that the slots are vertical and facing one another.
- Attach both springs from the spring module to the lugs on the cross bar (angled side).
- Hang the large loop of string from the lug on the flat side.

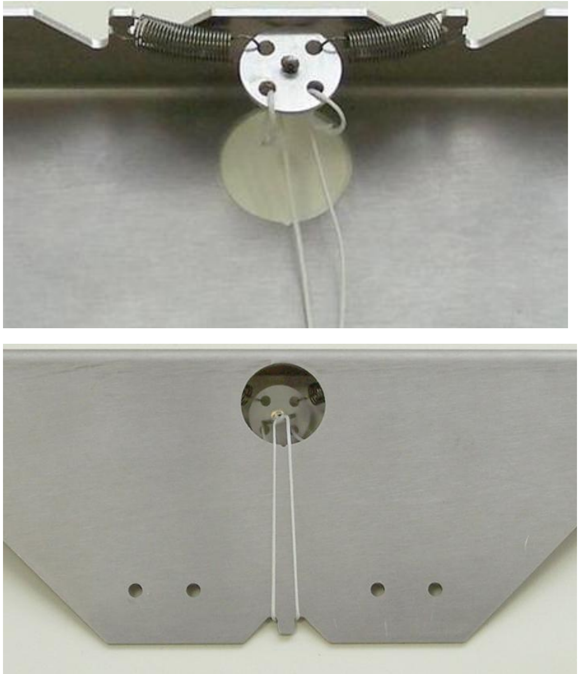

Fig. 3 Assembly of spring module

- Connect the springs and vector plate to the hook of a dynamic force sensor with a small loop of string and carefully pull everything taut.
- Attach the force sensor with the screw tightened by hand.
- Attach the second force sensor in the same way.

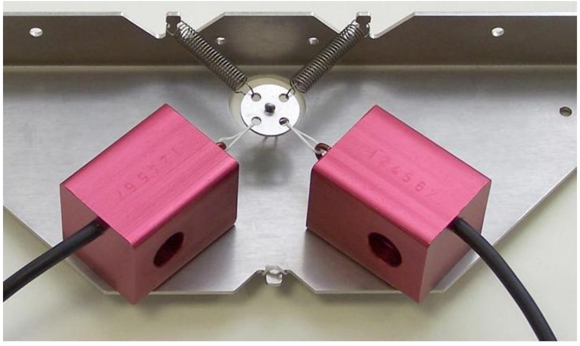

Fig. 4 Attachment of dynamic force sensors to spring module

- Pull the string through the eyelet of the spring module (in the middle of the metal disc).
- Thread the end of the string through the two holes of the length adjustment slider.

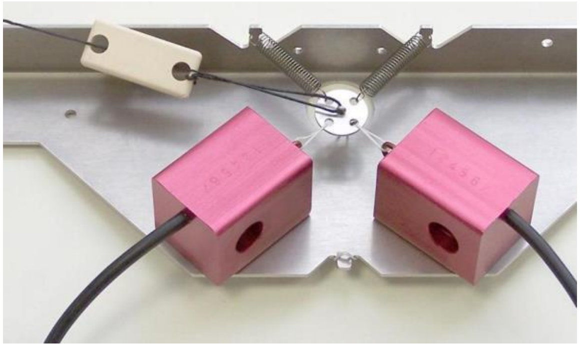

Fig. 5 Set up of string

- Clamp the cross bar into the slots of the two double clamps, suspend a weight from the end of the string and set up the height of the pendulum using the length adjustment slider.

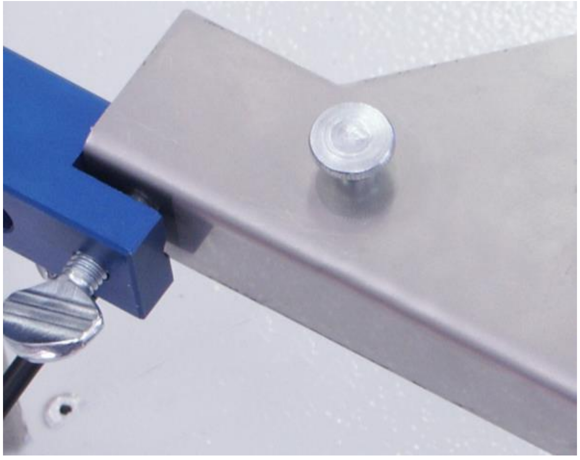

Fig. 6 Attachment of cross bar in double clamp

- Connect the force sensors to the inputs for channels A and B of the MEC amplifier board.
- Connect outputs A and B of the MEC control unit to channels CH1 and CH2 of the oscilloscope.

EXPERIMENT PROCEDURE

- Set the oscilloscope time base time/div to 1 s, select a vertical deflection for channels CH1 and CH2 of 50 mV DC and set the trigger to “Edge” mode, “Normal” sweep, “Source CH1” and “Slope +”.
- Slightly deflect the string pendulum and allow it to oscillate in a plane which bisects the alignment of the two force sensors (oscillation path a in Fig. 2). Observe the oscilloscope trace and save it.
- Slightly deflect the string pendulum and allow it to oscillate in a plane which is perpendicular to the one which bisects the two force sensors (oscillation path b in Fig. 2). Observe the oscilloscope trace and save it.
- Slightly deflect the string pendulum and allow it to oscillate in a circle (oscillation path c in Fig. 2). Observe the oscilloscope trace and save it.

SAMPLE MEASUREMENT AND EVALUATION

When the pendulum is oscillating in the plane of the bisecting angle between the sensors, the two sensors will experience symmetric loading (oscillation path a in Fig. 2). The signals from the two force sensors will be in phase, i.e. the phase shift between them will be $\varphi = 0°$ (Fig. 7).

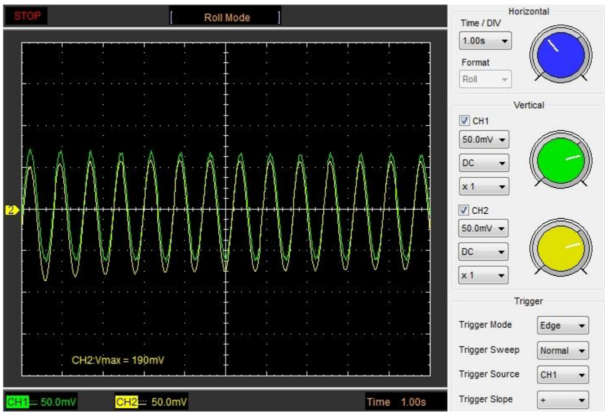

Fig. 7: Oscillation components for a string pendulum swinging along the line bisecting the two force sensors

When the pendulum is oscillating in the plane perpendicular to the bisecting angle between the sensors, the two sensors will experience asymmetric loading (oscillation path b in Fig. 2). The signals from the two force sensors will be wholly out of phase, i.e. the phase shift between them will be $\varphi = 180°$ (Fig. 8).

Fig. 8: Oscillation components for a string pendulum swinging along the line perpendicular to that bisecting the two force sensors

The circular oscillation is a superimposition of the oscillations along the plane of the bisecting angle between the sensors and the angle perpendicular to it with a phase shift of $\varphi = 90°$ (Fig. 9).

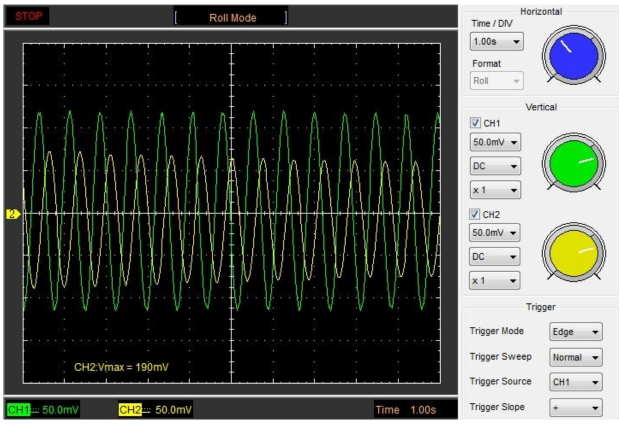

Fig. 9: Oscillation components for a string pendulum describing a circle