Mechanics

Rotational motions of a rigid body

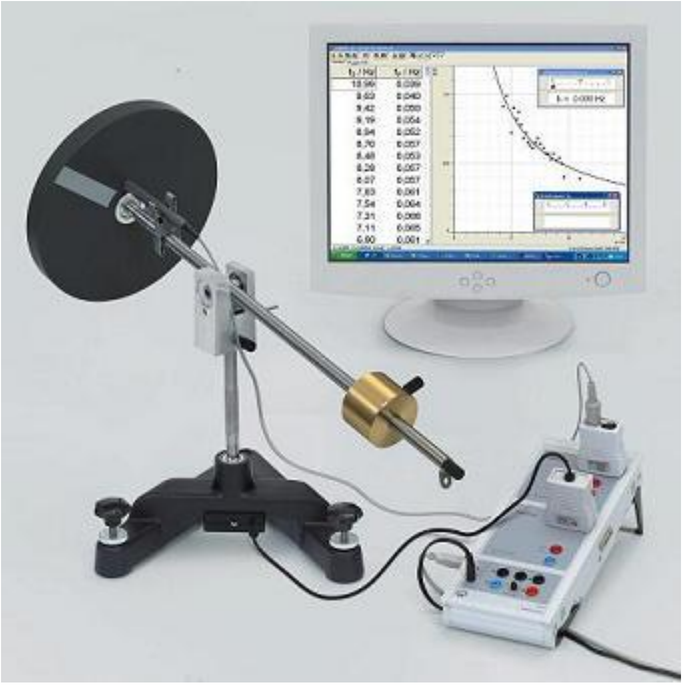
Motions of a gyroscope

Precession of a gyroscope

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

Precession of a gyroscope



can also be carried out with Pocket-CASSY

Principle

In the experiment, the precession frequency f_P of a gyroscope is investigated as a function of the exerted force F, i.e. the torque M = F · d and the rotational frequency f_D of the gyroscope disk.

The following relationship applies:

$$f_P = \frac{1}{4\pi^2} \cdot \frac{M}{J_S} \cdot \frac{1}{f_D}$$

The moment of inertia of the gyroscope disk is given approximately by:

$$J_S = \frac{m}{2} \cdot r^2$$

Experiment description

The precession frequency (frequency f_{B1}) is measured directly using the rotary motion sensor. The rotational frequency is determined by means of the reflection light barrier. To do this, the period T_D of the rotational motion of the gyroscope disk is measured, and from this the rotational frequency $f_D = 1/T_D$ is calculated.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	Rotary motion sensor S	524 082
1	Timer S	524 074
1	Reflection light barrier	337 468
1	Gyroscope	348 20
1	Double spring clip	590 021
1	Set of weights, each 50 g	342 61
1	PC with Windows XP/Vista/7/8	

Experiment setup (see diagram)

- Attach the reflection light barrier by means of the spring clip approx. 1 cm in front of the gyroscope disk. The supply cable is to be laid in such a way that it does not exert any forces on the gyroscope and so that the gyroscope can rotate freely for at least one turn.

- Fit the rotary motion sensor onto the gyroscope axis from below and fix it with the thumb screw.
- Shift the balancing mass so that the gyroscope is balancing, i.e. it is initially free of forces. Then hang a weight (50 g) on the end of the gyroscope rod on the same side as the balancing mass.
- The gyroscope should be precisely horizontally aligned above the adjustment screws on the foot.

Carrying out the experiment

- Load settings
- Testing of the correct adjustment of the reflection light barrier
  Start the gyroscope disk by hand. The rotational frequency (approx. 1 Hz) should be displayed. If necessary, move the reflection light barrier slightly.
- Test of the correct adjustment of the rotary motion sensor
  Rotate the gyroscope slowly about its vertical axis, the precession frequency (approx. 0.05 Hz) should be displayed after a short time.
- Start the gyroscope disk rotating rapidly by means of a piece of string. The maximum rotational frequency is approx. 10 Hz.
- Allow the gyroscope to precess and - once the gyroscope precesses uniformly - take a measurement by means of ⏱.
  The precession motion must not be overlaid by the nutation movement. The precession of the gyroscope is best obtained by starting up the gyroscope without nutation. Rotate the gyroscope back and start precession repeatedly for decreasing rotational frequencies and make measurements. If necessary, the gyroscope disk may be braked somewhat.
- Repeat the experiment with two suspended weights (100 g).

Evaluation

In the diagram of the dependency of the precession frequency f_P on the rotational frequency f_D a hyperbola is found, or, in the diagram of f_P plotted against $1/f_D$ a straight line, i.e. $f_P \propto 1/f_D$. The gradient of the straight line is the proportionality factor

$$\frac{m_2 \cdot g \cdot d}{4\pi^2 \cdot J_S},$$

for the example with one weight 0.45, with two weights 0.91.

With the estimated moment of inertia (with the simplifying assumption of an homogeneous and point mass)

$J_S = ½m \cdot r^2 \approx 0.010\ kg \cdot m^2$ (with m = 1.54 kg, r = 11.5 cm)

results, with a single weight (m_2 = 50 g), in a proportionality factor of 0.43 or with two weights (m_2 = 0.1 kg) of 0.86.