Mechanics

Rotational motions of a rigid body

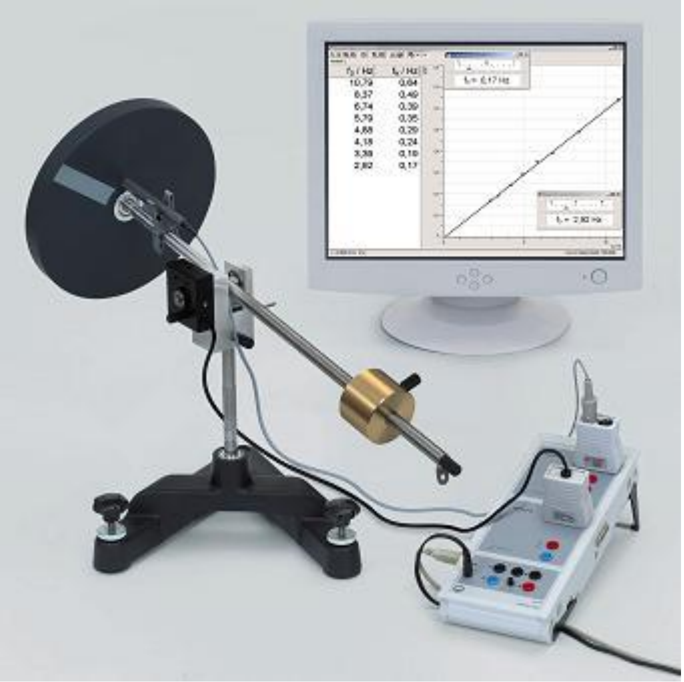
Motions of a gyroscope

Nutation of a gyroscope

Description from CASSY Lab 2

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

Gyroscope nutation



✓ can also be carried out with Pocket-CASSY

Principle

In the experiment, the nutation frequency f_N of a free gyroscope as a function of the rotational frequency f_D for the gyroscope disk is being investigated.

The relationship $f_D = J_S/J_K \cdot f_N$ applies

with $J_S = ½m \cdot r^2$: moment of inertia of the gyroscope disk about its rotational axis
and J_K: moment of inertia of the gyroscope about the gyroscope axis (point of suspension)

The moment of inertia of the gyroscope J_K is essentially the combination of the moments of inertia of the gyroscope rod J_1, the gyroscope disk J_2 and the balancing mass J_3 about the rotational axis.

For J_1, with the help of the parallel axes theorem: $J_1 = m_{St}/12 \cdot l^2 + m_{St} \cdot s^2$, applies,

with l: rod length, m_{St}: rod mass, s: distance of the gyroscope axis from the center of gravity (center) of the rod.

For J_2: $J_2 = m_{KS} \cdot a_{KS}^2$ applies,

with m_{KS}: mass of the gyroscope disk, a_{KS}: distance from the gyroscope axis.

J_3 is calculated similarly (with m_{AM}: balancing mass).

Experiment description

The nutation frequency is determined by means of a rotary motion sensor which is fitted to the gyroscope axis. In addition, the time of oscillation T_N of the vertical component of the nutation motion of the gyroscope is measured, and from this the nutation frequency $f_N = 1/T_N$ is calculated. 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	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.
- Fit the rotary motion sensor from below onto the gyroscope axis and fix with the thumb screw.
- 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.
- Shift the balancing mass so that the gyroscope is balancing, i.e. it is free of forces.

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
  Move the gyroscope uniformly up and down about its axis. The nutation frequency should be displayed (approx. 1 Hz).
- Start the gyroscope disk rotating rapidly by means of a piece of string. The maximum rotational frequency is approx. 10 Hz.
- Start the gyroscope nutation by gently pushing it.
- Record the measured value with ⏱.
- Start up nutation repeatedly for slowly decreasing rotational frequencies and make measurements. If necessary, the gyroscope disk may be braked somewhat.

Evaluation

In the diagram of the nutation frequency f_N as a function of the rotational frequency f_D a straight line appears, i.e. $f_N \propto f_D$. The gradient of the straight line is the proportionality factor J_S/J_K; in the example $J_S/J_K = 0.0659$.

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

$J_S = ½m \cdot r^2 \approx 0.010\ \text{kg} \cdot \text{m}^2$ (with $m = 1.54$ kg, $r = 11.5$ cm)
$J_1 = m_{St}/12 \cdot l^2 + m_{St} \cdot s^2 \approx 0.056\ \text{kg} \cdot \text{m}^2$ (with $m_{St} = 0.50$ kg, $l = 57$ cm, $s = 6.6$ cm)
$J_2 = m_{KS} \cdot a_{KS}^2 \approx 0.056\ \text{kg} \cdot \text{m}^2$ (with $m_{KS} = 1.54$ kg, $a_{KS} = 19$ cm)
$J_3 = m_{AM} \cdot a_{AM}^2 \approx 0.063\ \text{kg} \cdot \text{m}^2$ (with $m_{AM} = 1$ kg, $a_{AM} = 25$ cm)
$J_K = J_1 + J_2 + J_3 \approx 0{,}136\ \text{kg} \cdot \text{m}^2$

results in $J_S/J_K \approx 0.074$.