3B SCIENTIFIC® PHYSICS

Gyroscope U52006

Accessories for Gyroscope U52010

Instruction sheet

9/05 ALF

① Disc

② Gyroscope axle

③ Bobbin

④ Set of accessories U52010

⑤ Tripod stand

⑥ Stand rod

⑦ Counterweight, large

⑧ Counterweight, small

⑨ Adjusting screw

⑩ Scale

⑪ Spirit level

The gyroscope is used for demonstration and experimental quantitative derivation of the laws of gyrostatics. The following topics can be dealt with experimentally:

- Moment of inertia of the disc
- Turning moment/angular momentum
- Precession
- Nutation

1. Safety instructions

- Make sure that the gyroscope is standing firmly on the surface
- Make sure no components of the gyroscope (disc, weights) can fall down.

2. Description, technical data

2.1 Gyroscope

The gyroscope includes a vertical stand rod ⑥ to which is attached a gyroscope axle ② that can be rotated vertically and horizontally on its bearings. A disc ① mounted on double ball bearings is fitted on one side of the axle. At the other end, there are two counterweights ⑦, ⑧ that can be moved to balance the axle. Fine adjustments can be made at the end of the axle by means of an adjusting screw ⑨. To generate external turning moments, a hanger with an additional weight is suspended from the axle. The angle of inclination of the axle is displayed on a scale ⑩ which is clear and easy to read. A spirit level ⑪ is provided so that the gyroscope can be

aligned to the horizontal. The disc can be made to rotate either manually or by means of a string. The double ball-race bearing guarantees almost frictionless rotation that goes on for an extended period of time. The open construction of the gyroscope facilitates excellent observation of the gyroscopic phenomena.

Scale:	−45° to +45°
Scale divisions:	1°
Disc:	250 mm Ø
Mass of disc:	1500 g
Mass of counterweights:	50 g, 1400 g
Total mass:	4650 g

2.2 Accessories for the gyroscope

The set of accessories for the gyroscope U52006 consists of an additional disc and a counterweight. It is used to demonstrate the cancellation of gyroscopic forces when two discs rotate in opposite directions with the same rotational speed.

3. Theory

A gyroscope is a rigid body that rotates around an axis that is fixed at one point. If no external turning moment is applied, the axis of the gyroscope (being equivalent to the axis of its angular momentum) maintains its position in space. If, however, an external force is applied to the axis, then this turning moment effects a change in angular momentum. As a result, the axis is laterally displaced. The gyroscope moves in a direction perpendicular to both its own axis and to the acting force. This motion is called precession. If an impulse is applied to the axis of the gyroscope when it is spinning normally, the resulting turning moment causes an additional angular motion and the gyroscope starts to wobble. This wobbling motion is called nutation. In general, both motions are superimposed on one another.

4. Operation

- Place the tripod stand ⑤ on a level, non-vibrating work surface.
- Insert and fix the stand rod ⑥ into the tripod stand.
- Insert the gyroscope axle ② into its bearing.
- Align the device in a horizontal position by using the spirit level ⑪.
- Slide the disc ① and the counterweights ⑦, ⑧ along the axle. Use the locking ring to securely fix the disc and balance the gyroscope. Use the adjusting screw ⑨ for making fine adjustments.
- Rotate the gyroscope manually or with the help of a string wound into the bobbin ③.

5. Examples of experiment

In order to conduct the experiments, the following additional equipment is required:
- Mechanical adding stopwatch U11901 for measuring the precession and nutation frequencies.

- Stand rod U15002 and bosshead U13250 for fixing the gyroscope.
- Light barrier U18020 and digital counter U21005 for measuring the period of rotation of the gyroscope disc.

5.1 Determining the moment of inertia I of the disc
- Set up the gyroscope as shown in Fig. 1 and balance it.
- A known turning moment D is applied to the disc. The resulting angular momentum $d\omega/dt$ is measured. The following equation applies:

$$\frac{d\omega}{dt} = \frac{D}{I}$$

- To apply this turning moment, wind a string around the bobbin, suspend a weight from one end of the string and allow the weight to fall.
- Turning moment $D = mgr$ (m = mass of accelerating weight and r = radius of bobbin).
- To determine the angular acceleration, measure the time Δt between releasing the disc and when the weight hits the floor.
- Next determine the angular velocity ω_E. To do so, use the light barrier to measure the period of one disc revolution. Before starting the experiment, glue a thin strip of paper onto the rim of the disc.
- The moment of inertia I is calculated using the equation:

$$\frac{d\omega}{dt} = \frac{\omega_E}{\Delta t} \qquad I = \frac{D\,\Delta t}{\omega_E}$$
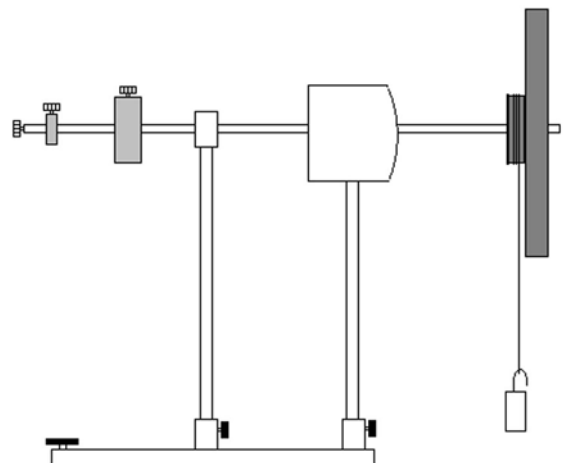

Fig. 1: Determining the moment of inertia of the disc

5.2 Precession
- The aim of the experiment is to demonstrate precession and to study the interdependence of the period of precession and the frequency of rotation of the disc.
- Set up the gyroscope as shown in Fig. 2 and balance it.

- Suspend an additional weight from the axle.
- Make the device rotate either manually or with the help of the string.
- The gyroscope displays precession.
- Determine the rotational frequency f of the disc and measure the period for one precession cycle T_P.
- The relation between f and T_P is calculated using the following equation:

$$I = \frac{D\,\Delta t}{\omega_E}$$

where R is the distance from the fulcrum of the gyroscope axis to the point where the additional weight m is attached.
- Take further measurements at decreasing rotational frequencies.
- Plot a graph of the frequency of rotation as a function of the period of a precession cycle.
- As an alternative to the method described above, the moment of inertia I of the disc can also be determined from the straight line gradient a.

$$f = \frac{m\,g\,R}{4\pi^2 a}$$

- Repeat the experiment using a different added weight. It can be determined that the precession frequency is approximately proportional to the added mass.
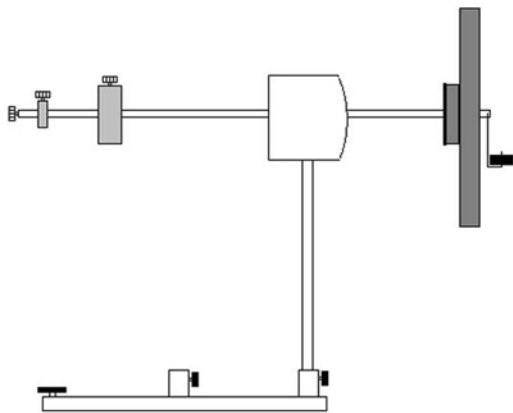

Fig. 2: Precession

5.3 Nutation
- The aim of the experiment is to demonstrate nutation and to study the interdependence between nutation frequency and frequency of rotation of the disc.
- Set up the gyroscope as shown in Fig. 3 and balance it.
- Make the disc rotate, either manually or with the help of the string.
- A slight lateral push to the spinning axis of the gyroscope will initiate nutation.
- In order to make a quantitative evaluation of the experiment, determine the period of a suitable number of nutation cycles.

- Subsequently measure the period of rotation of the disc.
- Make further measurements at slower disc frequencies
- Plot a graph of the nutation frequency as a function of the frequency of rotation of the disc.
- The nutation frequency is proportional to the rotation frequency.
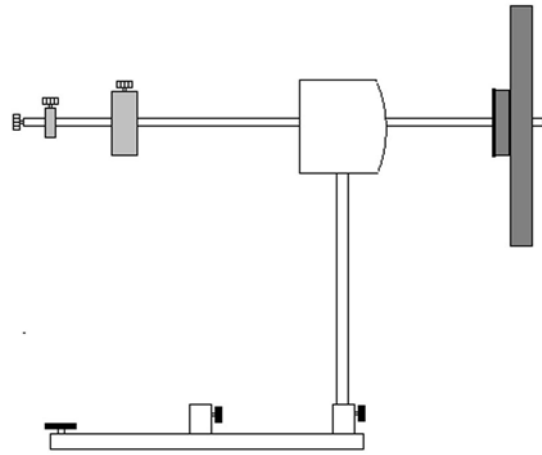

Fig. 3: Nutation

5.4 Cancellation of gyroscopic forces
- As shown in Fig. 4, slide a second disc and counterweight along the axis and secure with the locking ring.
- Balance the gyroscope.
- Attach the additional weight.
- Manually rotate the discs. Make sure they rotate in the same direction. To see the direction of rotation more clearly, you can glue a piece of white paper onto each disc.
- Demonstrate precession and nutation.
- Now wind each end of the string in opposite directions around a different bobbin.
- When the string is pulled, both discs begin to rotate in opposite directions with approximately the same rotational speed.
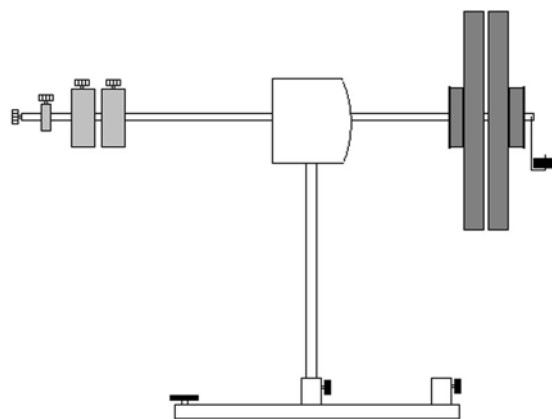- Demonstrate the cancellation of gyroscopic forces.

Fig. 4: Cancellation of gyroscopic forces