3B SCIENTIFIC® PHYSICS

...going one step further

Torsion Axle 1008662

Instruction sheet

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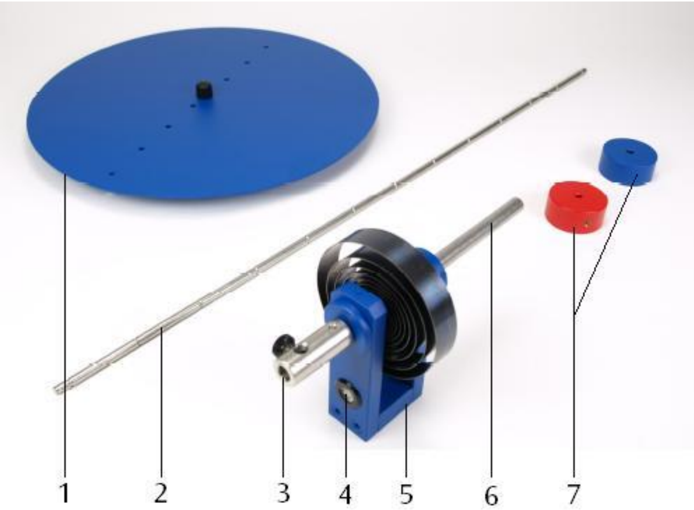

1 Circular disc
2 Cross bar
3 Mount for test bodies
4 Spirit level
5 Bracket with coiled spring
6 Support rod
7 Weights

1. Safety instructions

If the coiled spring is too tightly wound, there is the danger that high centrifugal forces cause the test bodies to be hurdled away.

- Do not displace the test bodies more than a maximum of 360° (180° is recommended).

2. Description

The torsion axle with its corresponding accessories and parts are used to investigate rotational oscillation and for determining the moments of inertia of various sample objects from the period of oscillation.

The torsion axle consists of a shaft with twin ball races which is coupled to a bracket by a coiled spring. A support rod permits assembly on a stand base or a table clamp. A spirit level is provided so that the torsion axle can be aligned to the horizontal. The test bodies are a cross bar with weights that can be moved along its length and a circular disc with one hole in the centre and eight away from the centre for determining moments of inertia for eccentric axes of rotation and confirming Steiner's theorem.

3. Equipment supplied

1 shaft with bracket, coiled spring, support rod and mount for test bodies

1 cross bar

2 weights

1 circular disc

4. Technical data

Restoring torque of the spring:	0.028 Nm/rad
Height of the torsion axle:	approx. 200 mm
Cross bar:	
Length:	620 mm
Mass:	approx. 135 g
Weights:	260 g each
Circular disc:	
Diameter:	320 mm
Mass:	495 g
Boreholes:	9
Borehole spacing:	20 mm

5. Accessories

Set of Test Bodies for Torsion Axle 1008663

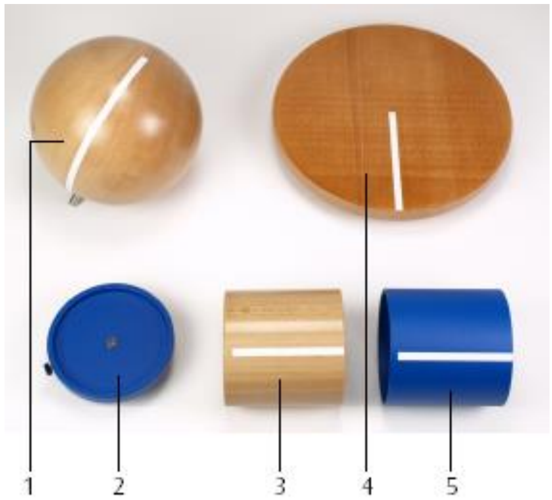

Fig. 1 Set of Test Bodies for Torsion Axle
1 Wooden sphere, 2 Mounting plate, 3 Solid cylinder, 4 Wooden disc, 5 Hollow cylinder

The accessories for the torsion axle consist of two cylinders with nearly identical weights but different weight distributions, a mounting plate for the cylinders, a wooden disc and a wooden sphere.

Hollow cylinder (metal):

External diameter:	90 mm
Height:	90 mm
Mass:	approx. 425 g

Solid cylinder (wood):

Diameter:	90 mm
Height:	90 mm
Mass:	approx. 425 g

Mounting plate:

Diameter:	100 mm
Mass:	approx. 122 g

Wooden disc:

Diameter:	220 mm
Height:	15 mm
Mass:	approx. 425 g
Moment of inertia:	0.51 kgm^2

Wooden sphere:

Diameter:	146 mm
Mass:	approx. 1190 g
Moment of inertia:	0.51 kgm^2

6. Theory

To determine various moments of inertia for different test bodies, these objects are placed on a ball-bearing supported shaft which has a coiled spring attached. The coiled spring is subjected to restoring torque *D*. The oscillation period *T* of the torsion pendulum results in the moment of inertia *J*.

$$T = 2\pi\sqrt{\frac{J}{D}} \qquad J = \frac{D}{4\pi^2}\cdot T^2$$

The values determined experimentally confirm the findings theoretically postulated for a body of the mass *m*, whose mass elements Δm rotate at a distance r_z around a fixed axis:

$$J = \sum_{z=1}^{n} \Delta m_z \cdot r_z^2 = \int r^2 \mathrm{d}m$$

7. Operating notes

- Mount the torsion axle in a tripod stand and align it horizontally using the spirit level.
- Do not adjust the screws that press the securing spheres to the rod. (They are adjusted so that the weights can be moved along the rod but are not forced outwards by centrifugal forces.)
- Always arrange the experiment so that the spring is compressed and not extended.
- Start the oscillation by turning the rod 180° (max. 360°).
- Determine the oscillation period from several measurements by forming the mean value out of e.g. 5 oscillations.
- Note down the exact value of the restoring torque *D* on the torsion axle or in the operating manual. This value is used to determine the moment of inertia *J* from the oscillation period *T*.

8. Experiments

To perform the experiments the following apparatus are required (recommended):

1 Stand Base Tripod, 185 mm	1002836
1 Digital Stopwatch	1002811
1 Precision Dynamometer 1 N	1003104
1 Set of Test Bodies for Torsion Axle	1008663

8.1 Determination of the restoring torque *D*

- Insert the rod without weights onto the torsion axle.
- Attach the 1 N dynamometer to the rod so that it acts perpendicularly to it.
- At distances of *r* = 10 cm, 15 cm and 20 cm from the centre of the rod measure the force

F needed to rotate the rod from its state of equilibrium by about α = 180°.

Torque: $M = F \cdot r$

Restoring torque: $D = \dfrac{M}{\alpha}$

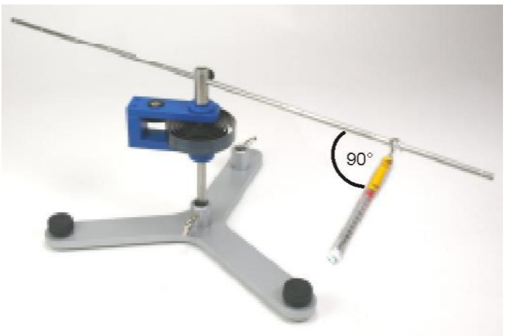

Fig. 2 Determination of the restoring torque

8.2 Dependency of the moment of inertia *J* on the distance *r*, in which a mass *m* rotates round a fixed axis

- Attach the rod without weights to the torsion axle.
- Determine the moment of inertia *J*(rod).
- Arrange the weights at symmetrical distances of *r* = 5 cm, 10 cm, 15 cm, 20 cm and 25 cm from the centre of the rod.
- Determine the moment of inertia *J*(rod + weights).
- Calculate the moment of inertia *J*(weights) = *J*(rod + weights) – *J*(rod).

Fig. 3 Dependency of the moment of inertia *J* on the distance *r*

8.3 Comparison of the moments of inertia of cylinders of the same weight but with different weight distribution

8.3.1 Wooden disc (WD)

- Attach the wooden disc (WD) to the torsion axle.
- Determine the moment of inertia *J*(WD).

Fig.4 Determination of the moment of inertia of a wooden disc

8.3.2 Solid cylinder (SC) and hollow cylinder (HC)

- Attach the mounting plate (P) to the torsion axle.
- Determine the moment of inertia *J*(P).
- Place a cylinder onto the mounting plate (P).
- Determine the moments of inertia *J*(SC + P) and *J*(HC + P).
- Determine the moments of inertia
  J(SC) = *J*(SC + P) – *J*(P)
  J(HC) = *J*(HC + P) – *J*(P) by subtracting.

Fig. 5 Comparison of the moments of inertia of cylinders

8.4 Determination of the moment of inertia of a sphere (S)

- Attach the sphere (S) to the torsion axle.
- Determine the moment of inertia *J*(S).

A comparison of the sphere with the wooden disc (refer to 8.3.1.) reveals that they both have the same moment of inertia. Spheres (S) and wooden discs (WD) have the same moment of inertia if the following holds true with regard to their mass *m* and their radii *R*:

$$m(WD) \cdot R(WD)^2 = \frac{4}{5} m(S) \cdot R(S)^2$$

Fig. 6 Determination of the moment of inertia of a sphere

8.5 Dependency of the moment of inertia *J* on the distance *a* between the rotation axis and the axis of the centre of gravity, verification of Steiner's theorem

- Attach the round disc to the torsion axle and align it horizontally.
- Start the disc turning about its centre of gravity (a = 0).
- Determine the moment of inertia J_0.
- Determine the moments of inertia J_a for different distances of a = 2 cm, 4 cm, 6 cm......16 cm between the rotation axis and the axis of the centre of gravity.
- Re-adjust the horizontal alignment of the disc after each change of distance a.
- Form the ratios $\frac{J_a - J_0}{a^2} = \text{constant}$

Thus Steiner's theorem $J_a = J_0 + ma^2$ is verified.

Fig. 7 Verification of Steiner's theorem