3B SCIENTIFIC® PHYSICS

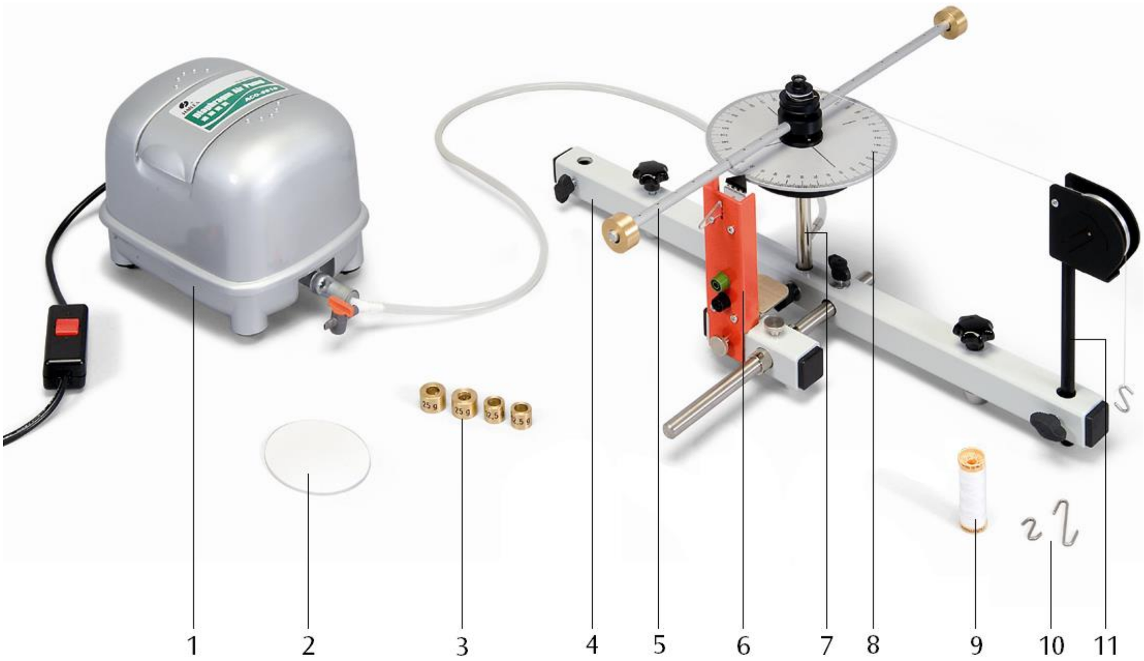
...going one step further

Rotating System on Air Bed

1000781 (115 V, 50/60 Hz)
1000782 (230 V, 50/60 Hz)

Instruction Sheet

09/15 ALF



1 Airflow generator (compressor)
2 Levelling washer
3 Additional weights
4 Stand rod, long
5 Transverse beam
6 Start/stop unit
7 Air-bearing unit
8 Rotating disc
9 Reel of cotton
10 S-hooks
11 Pulley

1. Safety Instructions

This rotating system on air bed is a sensitive instrument.

- Protect the rotating disc and the air bearing from mechanical damage.
- Protect the system from dirt, dust and liquids.

When using the laser reflection sensor, the appropriate regulations for the use of lasers must be observed.

- Do not look into the laser beam.

2. Description

The rotating system on air bed is an instrument for the study of frictionless rotational motion, encompassing the following topics:

- Steady rotational motion and rotational motion with uniform acceleration.
- Newton’s laws of motion applied to rotational motion.
- Moment of inertia and torque.

The apparatus is suitable both for presenting clear demonstrations and for students to investigate the physical laws of kinematics and dynamics in exercises and practical classes.

A small rotating disc marked with an angular scale supports a transversely mounted beam to which weights can be attached. The disc rests on an air-cushion so that it can rotate virtually without friction and the axis of rotation is preset by adjusting the centre. The weight of a driving mass hanging on a thread is transmitted to the disc via one simple pulley and a multiple pulley.

Because the frictional drag is minimal, even very small torques are enough to start the rotational motion. Consequently, the effect of the inertia contributed by the accelerating weight on the thread is less than one-thousandth of the total, even for the smallest moment of inertia that an be investigated. Moreover, measurement of the angular distance covered in a period of several seconds can be made very easily by the unaided eye and a hand-operated stopwatch.

For precise measurements it is possible to use a digital counter, which can be started by the built-in start/stop unit and stopped by a signal generated when the zero point of the scale passes through a light beam from a laser reflection sensor.

The air-flow generator for the rotating apparatus is designed to operate with a mains voltage of either 230 V ±10 % (1000782) or 115 V ±10 % (1000781).

A set of accessories is available for the rotating system on air bed (1000783) that allows for experiments on frictionless rotational oscillations and on frictionless rotational motion with a larger rotating disc.

3. Equipment Supplied

1 Rotational air-cushion bearing unit

1 Rotating disc with transverse beam

1 Multiple pulley

1 Start/stop unit

3 S-shaped hooks (2x 1 g, 1x 2 g)

1 Set of additional weights (2x 12.5 g, 2x 25 g, 2x 50 g)

1 Air-flow generator with mains adapter

1 Silicone-rubber tube with valve

1 Pulley

1 Stand rod, long

1 Stand rod, short

1 Stainless steel rod, 250 mm

1 Levelling washer

1 Reel of cotton-thread

4. Technical Data

Angle scale:	0 – 360°
Scale divisions:	1°
Length of transverse beam:	≈ 440 mm
Radial distance to holes in beam:	30 – 210 mm
Space between holes:	20 mm
Multiple pulley radii:	5/10/15 mm
Moment of inertia of rotating disc and transverse beam:	≈ 0.9 g m^2
Max. moment of inertia:	≈ 7.1 g m^2
Min. driving torque:	≈ 0.05 mN m
Max. driving torque:	≈ 0.60 mN m

5. Basic Principles

In analogy to Newton's law of motion for translational motion, the relationship between the torque M that is applied to a rigid body with a moment of inertia J, supported so that it can rotate, and the angular acceleration α is as follows

(1) $M = J \cdot \alpha$.

If the applied torque is constant, the body undergoes a rotational motion with a constant rate of angular acceleration.

In a time t from the start, the body rotates through the following angle:

(2) $\varphi = \frac{1}{2} \cdot \alpha \cdot t^2$.

This leads to the following expressions for the angular acceleration α:

(3) $\alpha = \frac{2 \cdot \varphi}{t^2}$

and, for the special case φ = 90°,

(4) $\alpha = \frac{\pi}{t^2}$.

The torque M results from the weight of an accelerating mass m_M acting at the distance r_M from the axis of rotation of the body, and is therefore:

(5) $M = r_M \cdot m_M \cdot g$

where g = 9.81 m/s², the gravitational acceleration constant.

If two additional masses m_J are attached to the transverse beam of the rotating system at a fixed distance r_J from the axis of rotation, the moment of inertia is increased from the initial value J_0 (without added masses) to:

(6) $J = J_0 + 2 \cdot m_J \cdot r_J^2$

6. Experiment Procedure

6.1 Setting up (see Figs. 1 and 2)

- Attach the stainless steel rod (h) to the long stand rod (f) and secure it.
- Insert the air-cushion bearing unit (j) in a hole in the long stand rod (f) and tighten the locking screw.
- Attach the pulley (n) to a long supporting rod (f) and secure it with a locking screw.
- Attach the start/stop unit to the short supporting tube (e), secure it, and slide it onto the stainless steel rod (h).

Before completing the set-up and beginning the experiment, the rotating system must be made level.

- Place the levelling disc in the circular recess of the air-cushion bearing unit.
- Attach the tube from the compressor to the inlet connector (k).
- Connect the compressor to the mains and switch it on.
- The two adjustment screws (g and m) allow inclination with respect to the horizontal to be adjusted in two planes (see Fig. 3).

The levelling is satisfactory when the levelling disc spins around evenly over the surface of the air-bearing unit.

- Place the rotating disc (i), together with the tranverse and the multiple pulley, on the air-cushion bearing unit (j).
- Push the start/stop unit up to the rotating disc and secure it with the locking screw. The foam pad of the pointer (a) should be in slight contact with the edge of the rotating disc.

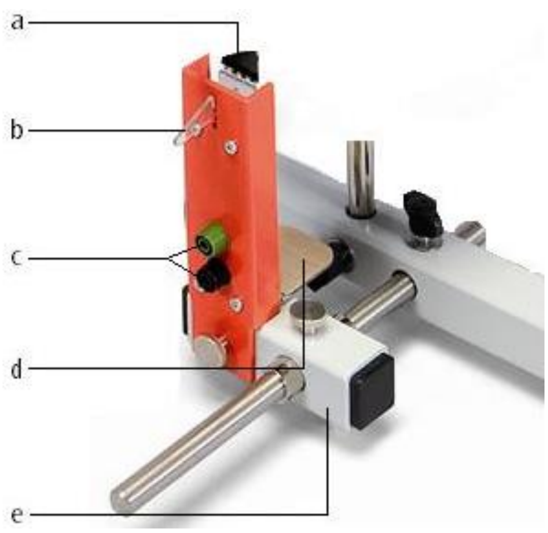


Fig. 1 Set-up for the start/stop unit: a pointer, b starting lever, c sockets for starter, d bracket for laser reflection sensor, e short stand rod

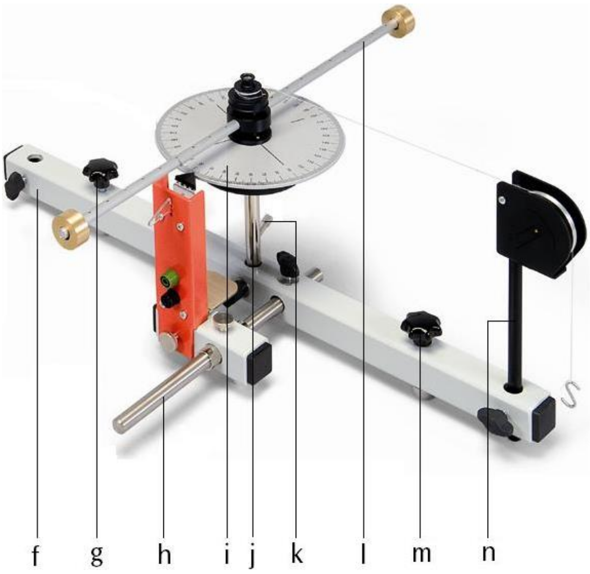


Fig. 2 Set-up of the rotating system: f long stand rod, g and m levelling screws, h stainless steel rod,

i rotating disc, j air-cushion bearing unit, k tube inlet,

l transverse beam with graduated pulley and additional weights, n pulley

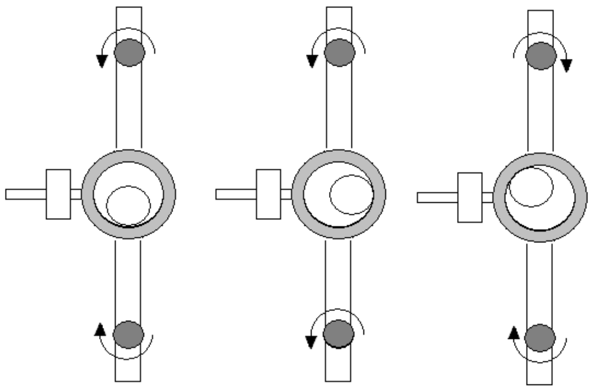


Fig. 3 Levelling the rotating system

6.2 Regulating the air supply

- Use only the valve (p) to regulate the airflow.

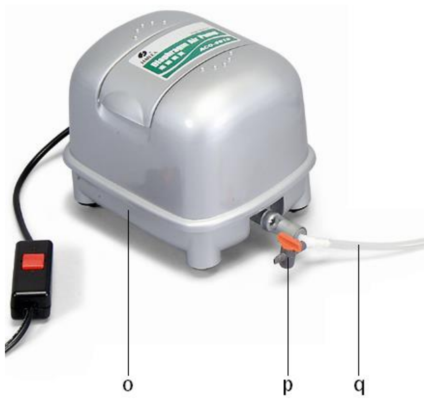


Fig. 4 Air supply controls: o airflow generator (compressor), p valve, q tube

7. Sample Experiments

To make time measurements the following instruments are recommended:

1 Mechanical stopwatch 1003369

or

1 Laser reflection sensor 1001034

and

1 Digital counter (230 V, 50/60 Hz) -1001033

or

1 Digital counter (115 V, 50/60 Hz) 1001032

7.1 Uniformly accelerated rotation

7.1.1 Making a graph of rotation angle versus time

Recommended parameters:

Accelerating mass m_M = 2 g

Multiple pulley radius r_M = 10 mm

Additional weight m_J = 25 g, distance r_J = 170 mm

Rotation angles φ = 10°, 40°, 90°, 160°, 250°

- Slide the two additional weights onto the transverse beam at the same distance from the axis of rotation.
- Attach a thread to the metal peg on the rotating disc and wind about 5-6 turns around a groove of the multiple pulley.
- Run the other end of the thread over the pulley and tie one of the S-shaped hooks firmly onto the end.
- Position the system so that the S-shaped hook hangs over an edge of the work-bench.
- Turn the rotating disc to the desired angle position and restrain it with the pointer.
- Switch on the compressor.
- Press the lever down to start the rotation, and simultaneously start the stopwatch for the time measurement.
- When the zero mark passes the position of the pointer, stop the time measurement, read the time, and write it down.
- Determine the times for different angles of rotation and plot a t-φ diagram.

For the parameters recommended above, the times are as follows:

10°	40°	90°	160°	250°
2 s	4 s	6 s	8	10 s

7.2 Angular acceleration as a function of torque

7.2.1 Angular acceleration with different accelerating masses

Recommended parameters:

Angle of rotation φ = 90°

Additional weight m_J = 50 g, distance r_J = 210 mm

Multiple pulley radius r_M = 10 mm

Accelerating masses m_M = 1 g, 2 g, 3 g, 4 g

- Set up the experiment as described under 6.1.
- Determine the times for the same angle of rotation with different accelerator masses m_M and calculate the corresponding angular accelerations α.
- Display the dependence of the angular acceleration α on the accelerator mass in an m_M-α diagram.

7.2.2 Angular acceleration with different multiple pulley radius

Recommended parameters:

Angle of rotation φ = 90°

Additional weight m_J = 50 g, distance r_J = 210 mm

Accelerating mass m_M = 2 g

Multiple pulley radii r_M = 5 mm, 10 mm, 15 mm

- Set up the experiment as described under 6.1.
- Determine the times for the same angle of rotation with differing pulley radii r_M and calculate the corresponding angular accelerations α.
- Display the dependence of the angular acceleration α on the radius of the multiple pulley r_M in an r_M-α diagram.

7.3 Angular acceleration as a function of the moment of inertia

7.3.1 Moment of inertia as a function of the additional weight

Recommended parameters:

Angle of rotation φ = 90°

Accelerating mass m_M = 2 g

Multiple pulley radius r_M = 10 mm

Distance r_J = 210 mm

Additional weights m_J = 0 g, 12.5 g, 25 g, 50 g

- Set up the experiment as described under 6.1.
- Determine the times for the same angle of rotation with different additional masses m_J and the same distance r_J, and calculate the corresponding moments of inertia J using Equations 4, 5 and 1.
- Display the dependence of the moment of inertia J on the additional mass m_J in an m_J-J diagram.

7.3.2 Moment of inertia as a function of the distance of the additional masses from the axis of rotation

Recommended parameters:

angle of rotation φ = 90°

accelerator mass m_M = 2 g

graduated pulley radius r_M = 10 mm

additional mass m_J = 50 g

distances r_J = 30 mm, 50 mm, 70 mm, …210 mm

- Set up the experiment as described under 6.1.
- Determine the times for the same angle of rotation with different distances r_J of the additional mass and calculate the corresponding moments of inertia J using Equations 4, 5 and 1.
- Display the dependence of the moment of inertia J on the distance r_J of the additional mass in an r_J-J diagram.

7.4 Time measurements using a digital counter and the laser reflection sensor

By using the start/stop unit and the laser reflection sensor, it is possible to make exact measurements over defined angular segments (see Fig. 1). Operating the lever (b) releases the brake that is holding the disc, and simultaneously a switch contact between the two sockets (c) is opened and starts the time measurement. A laser reflection sensor can be used to stop the time measurement at a predetermined position without touching the disc and without a time delay.

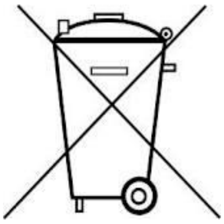
Warning: do not look into the laser beam!

- Place a laser reflection sensor on the bracket of the start/stop unit (magnetic holding mechanism).
- Connect the start/stop unit to the counter’s start signal input and the laser reflection sensor to the counter’s stop signal input.
- Position the laser reflection sensor so that the light beam passes through the hole at the 0° position. (Tip: cover the hole with a strip of paper – the laser light is easily visible through the paper.)
- Turn the rotating disc to the desired position on the scale and hold it there with the pointer by moving the lever to its upper position. The pointer should be only in slight contact with the edge of the disc.
- Press the lever down to start the rotation and the time measurement.

The time measurement stops when the light from the laser falls on the hole at the 0° position or on a mark on the underside of the large rotating disc (including in the set of additional accessories).

8. Disposal

- The packaging should be disposed of at local recycling points.
- Should you need to dispose of the equipment itself, never throw it away in normal domestic waste. Local regulations for the disposal of electrical equipment will apply.



- Do not dispose of the battery in the regular household garbage. Follow the local regulations (In Germany: BattG; EU: 2006/66/EG).