Experiment 1

Path-time diagrams of rotational motions

1- Objects of the experiment

- Determination of the angular displacement time diagram
- Determination of the mean angular velocity
- Determination of the angular acceleration

2- Principles

In this experiment, the rotational motion is investigated analogously to the translational motion. Translational motions are described in terms of path $\underline{s}$, time $\underline{t}$, velocity $\underline{v}$, and acceleration $\underline{a}$. Rotational motions are described in terms of angular displacement $\underline{\varphi}$, time $\underline{t}$, angular velocity $\underline{\omega}$, and angular acceleration $\underline{\alpha}$.

For an object rotating about an axis, every point on the object has the same angular velocity ω. The angular velocity is the rate of change of angular displacement φ. The average angular velocity can be described by the relationship:

$$\overline{\omega} = \frac{\Delta\varphi}{\Delta t} \qquad (1)$$

The angular acceleration α is the rate of change of angular velocity ω. The average angular acceleration can be described by the relationship:

$$\overline{\alpha} = \frac{\Delta\omega}{\Delta t} \qquad (2)$$

If the angular acceleration α is constant, in analogy to the translational motion, the following equations representing a complete description of the uniformly accelerated rotational motion:

$$\varphi(t) = \varphi_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$ (Angular displacement) (3)

$$\omega(t) = \omega_0 + \alpha t$$ (Angular velocity) (4)

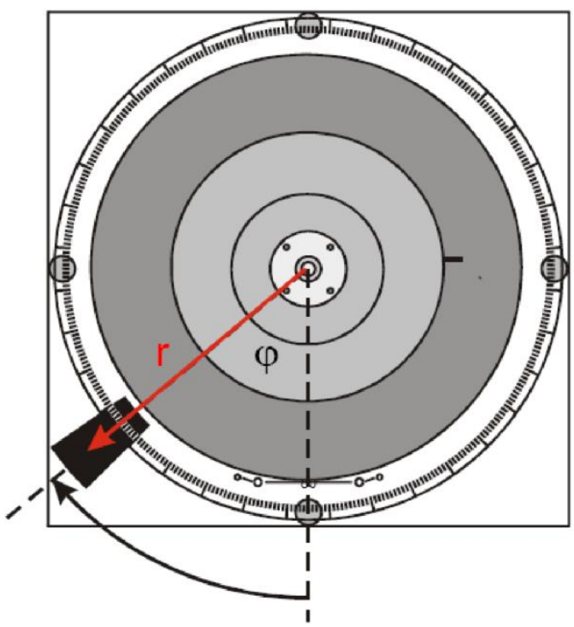
where:

ϕ_0 φ_0: Initial angular displacement

ω_0 ω_0: Initial angular velocity

α : Angular acceleration

In this experiment the rotational model is used to investigate the uniform rotational motion (ω constant), and the uniformly accelerated rotational motion (α constant).



***<u>Figure 1</u>**: Rotational motion of a mass (here the black flag) at radius r, from the center of rotation. φ angular displacement*

a) Uniform rotational motion

By choosing appropriate conditions for the initial angular displacement (φ_0 = 0) and the angular acceleration (α = 0) in equations (3) and (4) the following equations result for describing of the uniformly rotating flag (Figure 1.)

$$\varphi(t) = \omega_0 t \qquad (5)$$

$$\omega(t) = \omega_0 \qquad (6)$$

b) Uniformly accelerated rotational motion

By choosing appropriate conditions for the initial angular displacement (φ_0 = 0) and the angular velocity ($\omega_0 = 0$) in equations (3) and (4) the following equations result for describing of the uniformly accelerated rotating flag (Fig. 1.)

$$\varphi(t) = \frac{1}{2}\alpha t^2 \qquad (7)$$

$$\omega(t) = \alpha t \qquad (8)$$

3- List of Equipments

	Catalogue Number
1 Rotational model	347 23
2 Forked light barrier	337 46
2 Multi-core cable, l = 1.50 m	501 16
1 Counter S	575 471
1 Laboratory stand II, 16 x 13 cm	300 76
1 Simple bench clamp	301 07

4- Setup

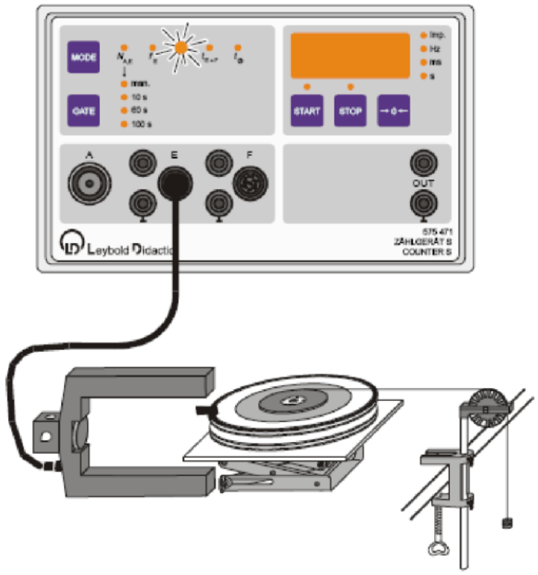


Figure 2. *Experimental setup to determine the angular displacement and angular velocity as function of time.*

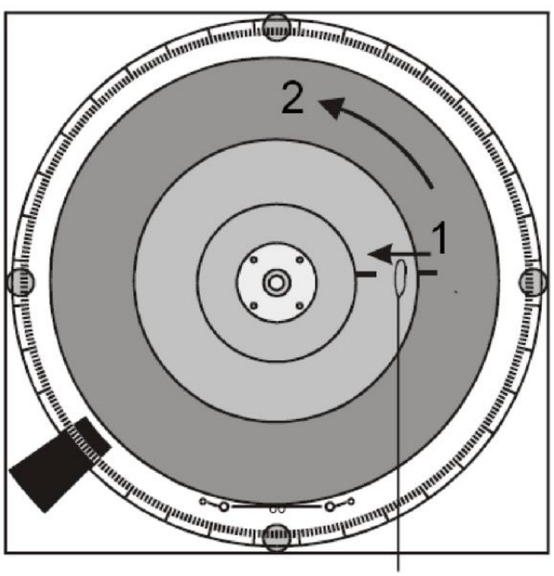


Figure 3. *Schematic sketch for setting the rotational model in uniform or uniformly accelerated rotational motion conveniently:*

1. Hook up the transmission thread to a pin by its loop.

2. Wind up the transmission thread by rotating the disk.

Set up the rotational model with one flag on the Laboratory stand as shown in Figure 2. Prepare a transmission thread of a length of approximately 100 cm to 150 cm with a loop at one end. Hook up the transmission thread to the pin of an extra disk (e.g. r = 2.5 cm) of the rotation model (Figure 3) and run it over the wheel which is attached by the bench clamp on the edge of the table. The accelerating force is generated e.g. by 3 small suspended weights of 1 g each (F = 0.0294 N).

Connect the forked light barrier via the multi-core cable to the input E of the counter S.

5- Carrying out the experiment

a) Uniform rotational motion

- Place the forked light barrier on an appropriate position in respect to the rotating flag to measure the time of circulation.
- Fix 3 weights of 1g to the transmission thread (to the end with no loop) and run it over the wheel.
- Hook up the transmission thread with its loop to the pin of an extra disk with e.g. a radius of r = 5cm (Figure 3).
- Wind up the transmission thread by rotating the disk of the rotational model, e.g. one turn to have reproducible starting conditions.
- For the time measurements select “manual time measurement t_e” by toggling the mode button on the counter S.
- Set the rotational model into uniform rotational motion by accelerating the upper disks with the falling the weight. The thread will release itself after complete rewinding. Due to low friction of the rotational model the disk rotates now uniformly.
- Measure the time for one round manually (i.e. for an angle φ = 360°) by using the “Start” and the “Stop” button of the counter S.
- Repeat the measurement for 2, 3 and 4 turns and fill Table 1.

Hint: The interruption of light emitting diode of the forked light barrier by the rotating flag can be used as Start and Stop aid.

Table 1. *Time as function of angular displacement* φ

φ *(deg)*	φ *(rad)*	t_1 (s)	t_2 (s)	t_3 (s)	t_4 (s)	t_5 (s)	t_{avg} (s)
360							
720							
1080							
1440	y						x

- Prepare a sheet of graph paper for plotting φ *in radians* versus t_{avg}. You should make φ the vertical axis and t_{avg} the horizontal axis. Each axis should be labelled and appropriate units indicated. The graph should have a title.
- Plot your data on the graph.
- Draw best fit line to the points on your graph by using the method of least squares (see appendix).
- Determine the angular velocity

b) Uniformly accelerated rotational motion

- Fix 3 weights of 1g to the transmission thread (to the end with no loop) and lay it over the wheel.
- Hook up the transmission thread with its loop to the pin of an extra disk with e.g. a radius of r = 2.5 cm.
- Wind up the transmission thread by rotating the disk of the rotational model, e.g. 2 turns.

- Place the forked light barrier on an appropriate position in respect to the rotating flag (i.e. starting position) to measure the time t as function of the angle φ.

- For the time measurements select "manual time measurement t_e" by toggling the mode button on the counter S.

- Measure the time for various angles φ manually:

Push the "Start" button of the counter S when releasing the weight, i.e. when the rotational model starts to rotate.

Push the "Stop" button of the counter S when the light emitting diode of the forked light barrier is interrupted by the rotating flag of the counter S.

Table 2. *Time as function of angular displacement*

φ *(deg)*	φ *(rad)*	t_1 (s)	t_2 (s)	t_3 (s)	t_4 (s)	t_5 (s)	t_{avg} (s)	t_{avg}^2 (s²)
30								
60								
90								
120								
150								
180								
210								
240								
270								

- Prepare a sheet of graph paper for plotting φ *in radians* versus t_{avg}^2. You should make φ the vertical axis and t_{avg}^2 the horizontal axis. Each axis should be labelled and appropriate units indicated. The graph should have a title.
- Plot your data on the graph.
- Draw best fit line to the points on your graph by using the method of least squares (see appendix).
- Determine the angular acceleration