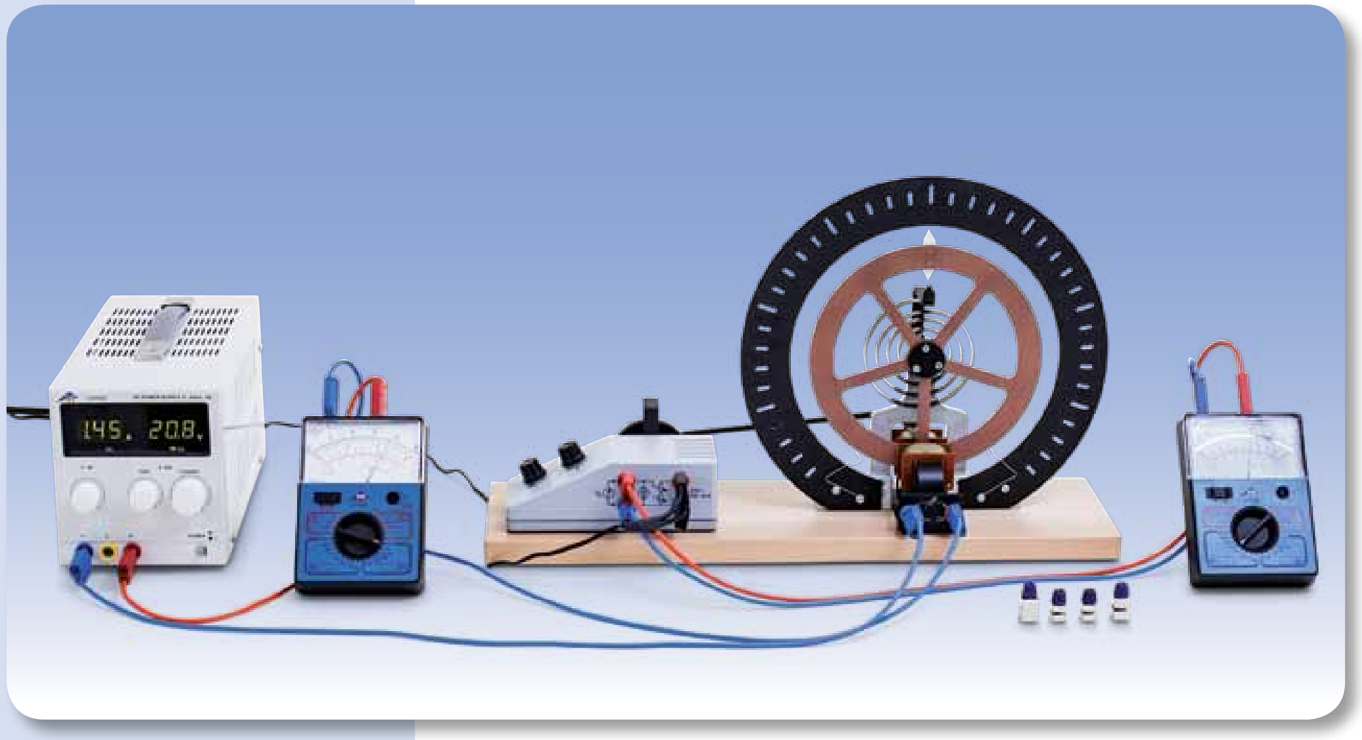
POHL'S TORSION PENDULUM



EXPERIMENT PROCEDURE

- Measure the amplitude of forced oscillations as a function of the excitation frequency for various degrees of damping.
- Observe the phase shift between the excitation and the actual oscillation for excitation frequencies which are very small and other which are very large.

OBJECTIVE

Measurement and analysis of forced harmonic rotary oscillation

SUMMARY

Pohl's wheel or rotating (torsional) pendulum allows for the investigation of forced harmonic rotary oscillation. For this purpose, the oscillating system is connected to an excitation linkage which is driven by an adjustable-speed DC motor so that the restoring spring periodically extends and compresses. In this experiment the amplitude is measured as a function of the excitation frequency for various degrees of damping and the phase shift between the excitation and the actual oscillation is observed.

REQUIRED APPARATUS

Quantity	Description	Number
1	Pohl's Torsion Pendulum	**1002956**
1	Mechanical Stopwatch, 15 min	**1003369**
1	Plug In Power Supply 24 V, 0.7 A (230 V, 50/60 Hz)	**1000681 or**
	Plug In Power Supply 24 V, 0.7 A (115V, 50/60 Hz)	**1000680**
1	DC Power Supply 0 – 20 V, 0 – 5 A (230 V, 50/60 Hz)	**1003312 or**
	DC Power Supply 0 – 20 V, 0 – 5 A (115 V, 50/60 Hz)	**1003311**
2	Analogue Multimeter AM50	**1003073**
1	Set of 15 Safety Experiment Leads, 75 cm	**1002843**

UE1050550

BASIC PRINCIPLES

Pohl's wheel or rotating (torsional) pendulum allows for the investigation of forced harmonic rotary oscillation. For this purpose, the oscillating system is connected to an excitation linkage which is driven by an adjustable-speed DC motor so that the restoring spring periodically extends and compresses.

The equation of motion for this system is as follows

$$\frac{d^2\varphi}{dt^2} + 2\cdot\delta\cdot\frac{d\varphi}{dt} + \omega_0^2\cdot\varphi = A\cdot\cos\left(\omega_E\cdot t\right) \tag{1}$$

where $\delta = \frac{k}{2J}$, $\omega_0^2 = \frac{D}{J}$, $A = \frac{M_0}{J}$

J: moment of inertia
D: spring constant
k: damping coefficient
M_0: amplitude of external torque
ω_E: angular frequency of external torque

The solution to this equation is composed of a uniform and a non-uniform component. The uniform component is equivalent to damped simple harmonic motion, as investigated in experiment UE1050500. This decreases exponentially over time and can be neglected by comparison with the non-uniform component after a short period of settling.
The non-uniform component

$$\varphi(t) = \varphi_E\cdot\cos\left(\omega_E\cdot t - \psi_E\right) \tag{2}$$

is linked to the external torque, however, and remains non-negligible as long as that torque is present: Its amplitude is as follows:

$$\varphi_E = \frac{A_0}{\sqrt{\left(\omega_0^2 - \omega_E^2\right)^2 + 4\cdot\delta^2\cdot\omega_E^2}} \tag{3}$$

This becomes increasingly high the closer the excitation frequency ω_E is to the intrinsic resonant frequency ω_0 of the rotating pendulum. Resonance is said to occur when $\omega_E = \omega_0$.
The phase shift is shown below:

$$\psi_E = \arctan\left(\frac{2\cdot\delta\cdot\omega_E}{\omega_0^2 - \omega_E^2}\right) \tag{4}$$

This indicates that the deflection of the pendulum lags behind the excitation. For low frequencies it is close to zero but as the frequency increases, it rises, reaching 90° at the resonant frequency. For very high excitation frequencies, the excitation and oscillation frequencies end up being 180° out of phase.

EVALUATION

The amplitudes of the damped oscillations are plotted against the excitation frequency. This results in a selection of curves which can be described by equation (4) as long as the appropriate damping parameter δ is chosen.
There will be slight deviations from the damping values measured in experiment UE1050500. This is mainly due to the fact that the force of friction is not exactly proportional to the speed as assumed here.

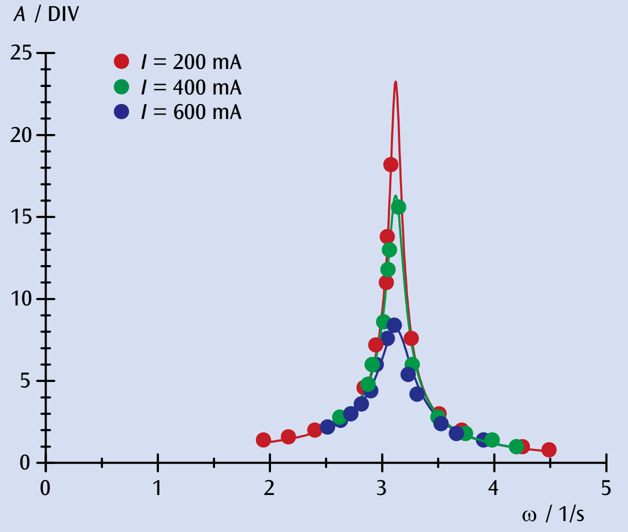


Fig. 1: Resonance curves for various degrees of damping