

# GP04 Student lab report

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## Abstract

The abstract should be a short 3-5 sentence paragraph. In it, you should state the hypothesis, what you did, and what you found. The abstract is meant to be a very short summary of your paper to follow. It is a good suggestion to write the abstract last in your report after you have written everything else. This will allow you to best summarize your work.

## 1 Introduction

Simple harmonic motion (SHM) plays a fundamental role throughout physics, appearing in systems ranging from oscillatory motion in classical mechanics to lattice vibrations and quantum harmonic oscillators in quantum mechanics. In an ideal simple harmonic oscillator, the restoring force acting on the system is directly proportional to the displacement from equilibrium and acts in the opposite direction, leading to periodic motion described by a second-order linear differential equation.

In realistic physical systems, however, oscillations cannot occur indefinitely without energy loss. Dissipative effects such as friction and air resistance introduce damping, causing the amplitude of oscillation to decrease over time. In addition, external forces may act on the oscillator and continuously supply energy to the system. When such a driving force is applied, the resulting motion depends strongly on the driving frequency, leading to phenomena such as resonance. By analysing and solving the equations of motion for free, damped, and driven oscillators, key physical quantities such as the oscillation period, amplitude, and phase response can be determined.

In this experiment, we investigate and verify the theoretical description of driven harmonic motion. Free oscillations, damped oscillations, and oscillations driven over a wide range of frequencies were studied experimentally. The effective spring constant, natural frequency, and damping constant of the oscillator were measured independently, allowing for quantitative comparisons between theoretical predictions and experimental results.

## 2 Theory

The rotational oscillator used in this experiment consists of a disk of mass  $m$  and radius  $R$  suspended from a torsion wire with torsion constant  $\kappa$ . According to Hooke's law for torsion:  $\tau = \kappa\Delta\theta = mgr$ , we can discover the formula of  $\kappa$ :

$$\kappa = \frac{mgr}{\Delta\theta} \quad (1)$$

The moment of inertia of the disk is given by  $I = \frac{1}{2}mR^2$ . The equation of motion for the angular displacement  $\theta(t)$  of the disk can be derived from Newton's second law for rotation:

$$I \frac{d^2\theta}{dt^2} + b \frac{d\theta}{dt} + \kappa\theta = \tau_{\text{drive}}(t)$$

## 3 Experimental Setup

In this section, you should explain your experiment in detail. The usual method is that you first explain what you did, then you explain how you did it. I.e. first explain the data you are trying to collect. Then explain (citing relevant equations as necessary) why this data is necessary in order to prove/disprove your hypothesis. Finally, explain how you collected the data, citing both the materials used as well as stating their purpose and what they are used to collect or to do. You can break up this section into two sections if you wish. The first would be materials and the second would be procedure.

## 4 Data

### 4.1 Measure the constant of the spring

Placing one brass weight and a plastic hook on one side of the spring, and measure the displacement of the spring. Without any additional weights, the spring is stretched by 0.05 m. With one brass weight, the measured  $\theta = -0.489(1)$  radians. Adding 20 grams on the left hand side of the spring, the measured  $\theta = 1.769(1)$  radians. Adding 50 grams on the left hand side of the spring, the measured  $\theta = 5.066(1)$  radians.

From measurements we also got the radius of the disk  $R = 26.26(2)$  mm. Given that  $g = 9.81\text{ms}^{-2}$ , from eq.1 we can calculate the torsion constant  $\kappa = 2.413(6) \times 10^{-3}\text{Nm rad}^{-1}$ .

## 5 Analysis

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