The Torsion Oscillator - Free and Driven Oscillations, and Resonance

Objectives:
- To become familiar with the use of torsion oscillator to investigate damped and forced oscillations and resonance.
- To measure the torsional constant of the system
- To measure the rotational inertia of the system
- To observe the under- damped, critically-damped and over-damped oscillations and determine of the damping constant
- To observe the forced oscillations and resonance - fit the theory to the observations.

Reading:
- Any introductory physics textbook
- Your textbook for PHY 401 or any books on Mechanics
- Instruction manual for TeachSpin Torsion Oscillator Manual

Experiments:
1. Get acquainted with the torsional oscillator
2. Measure the torsional constant $\Rightarrow \tau = -\kappa\,\theta$
3. Observe free oscillations and damping - determine the natural frequency and the damping constant.
4. Induce the forced oscillations of different frequency and observe the resonance. Measure the amplitude and phase of oscillation as a function of frequency.
   Fit the data with

$$\theta_{\mathbf{max}}(\omega) = \frac{C}{\sqrt{\left(\omega_\circ^2 - \omega^2\right)^2 + 4\gamma^2\omega^2}} \tag{1}$$

where, $\theta_{\mathbf{max}}(\omega)$ is the steady state amplitude amplitude, ω is the frequency, γ is the damping constant and C is a constant. Recall that the differential equation of the driven oscillator is

$$\ddot{\theta} + \gamma\,\dot{\theta} + \omega_o^2\theta = \frac{\tau_o}{I}\cos\omega_d t \tag{2}$$

where, $\omega_\circ$ and ω_d are oscillation frequencies without and with the damping. Look up the transient and steady state solutions of Eq. (2).

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Report

Your report should include: *Will discuss in lab/class*

Questions

1. What is the relationship between phase vs. driving frequency for a driven torsional harmonic oscillator?
2. What is the definition of quality factor, Q, and its relationship to the parameters described above.
3. What is the transient solution of Eq. (2)? That is, write an expression for $\theta(t)$ for the transient state.