Pendulum Lab Report

PHY180: Classical Mechanics

Javier Huang

Abstract

This research experiment investigated the effects of initial angle, length, and damping on the motion of a physical pendulum. A manually released pendulum was tracked using digital video analysis to measure angular displacement, period, and amplitude decay. The motion was modeled as a damped harmonic oscillator, where $\theta(t) = \theta_0 e^{-\frac{t}{\tau}} cos\left(\frac{2\pi t}{T} + \phi_0\right)$. The period dependence on amplitude was compared with both small-angle and large-angle theoretical predictions and was fitted with the power series relation $T = T_0(1 + B\theta_0 + C\theta_0^{\ 2} + \ ...)$, showing no measurable asymmetry ($B = 0.001 \pm 0.001\, rad^{-1}$) and a significant quadratic dependence ($C = 0.0608 \pm 0.0006\, rad^{-2}$). The small-angle approximation was valid for $|\theta_0| \leq 0.09\, rad$, where the period remained approximately constant. The period-length relationship was measured according to $T = 2\pi\sqrt{\frac{L}{g}} \approx kL^n$, producing experimental values of $k = 1.992 \pm 0.002$ and $n = 0.476 \pm 0.001$, similar to theoretical values of $k = 2$ and $n = 0.5$. The quality factor was calculated using $Q = \pi\frac{\tau}{T}$ and was found to vary quadratically with length, reaching a maximum of $Q = 500 \pm 20$ at $L = 0.4568 \pm 0.005\, m$. The results generally followed theoretical predictions but showed deviations due to non-ideal damping, measurement uncertainty, and limitations of the ideal pendulum model.