The Kater's Pendulum

Kushal Lodha & Shailendra Dhakad
QuazarTech, New Delhi

July 14, 2017

Abstract

In our quest to devise an experiment using to determine the precise value of g (the acceleration due to gravity) accurately, we use the Kater's Pendulum setup to see how far we can get in terms of precision and accuracy and whether this experiment, which is to become a part of Quazar's Mechanical Engineering Lab, can be made intuitive and interesting for students.

1 Notes for the Quazar Team

1.1 Manufacturing Defects in the Goodwill Pendulum

The rod was slightly bent. The knife-edges had a visible radius and were not straight. In fact, they allowed the pendulum to rock at the right angles to the plane of oscillation. There was considerable play between the rod and the masses as also, the ring holding the knife-edges. The cast-iron support was poorly finished. No microscope slides were provided.

1.2 How we corrected these Defects

We replaced the original rod with one made of hardened die-steel.

2 Apparatus and Specifications

2.1 The Physical Pendulum

Length = 1.25 m
Diameter = 12 mm
Weight & Material of the rod = 1.105 kg (Hardened Die-Steel)
Dimensions Weights & Materials of the adjustable masses
Invariance of the pendulum under inversions and 180^o rotations
Volumetric Symmetry of the pendulum Hardness, initial radius, rate of flattening & length of each knife-edge
Lateral and angular alignment of the knife-edges

2.2 Photo-gate & the associated circuitry

Least Count in time measurement = 4 μs
Width of Sensor Apperture = 9.525 mm
Triggering Options:

1. Continuous Acquisition
2. Schmitt trigger.

2.3 The Suspension Bracket or the Stand

2.4 Specs for the Complete System

Noise level of the time-measurement
Invariance of the Pendulum under inversions and 180^o rotations
Volumetric symmetry and mass asymmetry of Pendulum
Repeatability Checks

- Order 0 Check: Variation of time period if released from same initial conditions
- Order 1 Check: Variation of time period if released from different release angle
- Order 2 Check: Variation of time period if balanced at different position of adjustable masses
- Order 3 Check: Variation of Time period if balanced at different sepration between knife edges

3 The Experimental Procedure at Level Zero

3.1 Balancing the Pendulum with and without the Simulation Program

3.2 g to the first place of decimal

4 Improving Resolution

4.1 The jitter/noise in the Time-Period

4.1.1 Measuring and characterizing the noise

4.1.2 Identification of the sources of noise

4.1.3 Reduction of the noise

4.2 The least-count for time

4.2.1 The least-count of QDAL414B

4.2.2 The least-count of the Comparator Circuit

5 Improving Precision or Repeatability

5.1 Release mechanism

The pendulum has to be released (1) with zero velocity (Soln: Hold the pendulum with the help of a thread. Ensure that the plane defined by the pendulum and the thread coincides with the plane of oscillation. Use (the plane of) the wall as a reference. Release the pendulum by burning the thread with the help of a lighter) and (2) from a fixed and precisely measurable angle. (For this we need a protractor centered at the fulcrum. We can vary the positions of the masses, but keep the knife-edges fixed. In that case, the radius of the protractor can be kept invariant).

5.2 Alignments

5.2.1 The Knife-edges: Collinearity, Radii & Placement

5.2.2 Adjustment of the Photo-gate

5.3 Eliminating Parallax in the Angle-Measurement

6 Characterizing Air-Resistance

6.1 Cancellation of Buoyancy and Added Mass Effects

Bessel showed that if the volume distribution of the pendulum is nevertheless made symmetric about the point midway between the pivots(in our case center of rod), two of signifigant air corrections disappear. These are the corrections for buoyancy of the pendulum in air and for the inertia due to air dragged by the pendulum as it oscillates (Added mass).

6.2 The Linear and Quadratic Damping Coefficients

6.3 Friction at the Knife-edges

7 The Amplitude-dependence of T

8 Measuring the Length

8.1 Using scales, verniers and gauges

8.2 Using Interferometry

9 Results

9.1 The First Place of Decimal

9.2 The Second Place of Decimal

9.3 The Third Place of Decimal

9.4 The Fourth Place of Decimal

10 Discussion

11 Reference