Heading

Experiment Title: Measuring the Speed of Sound in Air
Experiment Start Date: 28th October 2021
Experiment Start Time: circa 09.10

Aims

Briefly outline the aims of the experiment.

An experiment was carried out which utilises a stiff pendulum, as well as a torsion pendulum in order to determine the value for gravitational acceleration, *g*, in Blackett.

Background

Briefly outline the theoretical background of the experiment, but do not just repeat what is in the lab manual. Include all important equations that will be used for data analysis.
Include any key references .

An experiment was carried out to calculate the value of *g*, composed of two parts: using the stiff pendulum in order to time the length of a single oscillation, as well as the use of a torsion pendulum for the measurement of rotational motion *(i.e. moment of inertia)*.

The equation for the period of the stiff pendulum, denoted T_s is given by the following equation that is independent of the amplitude of the (small-angled) oscillations (1):

$$T_S = \sqrt{\frac{4\pi^2 I}{Mgh}}$$

where I is the *moment of inertia of the pendulum about the knife edge*, h is the *distance between knife edge and Centre of Mass of the Pendulum*, and M is the *mass of the pendulum*. Rearranging for g in the equation, we have (2):

$$g = \frac{4\pi^2 I}{MhT_S^2}\,.$$

Consequently, measurements (or their derived values) were obtained for T, M, h and I.

The second half of the experiment concerned rotational movement. The wire is rotated through by an angle of θ and the wire resists this twisting motion through a restoring torque, τ. For small angular displacements, this is given by the following rotational form of Hooke's law (3):

$$\tau = -\kappa\theta\,,$$

The constant κ is known as the *torsion coefficient*. Releasing the twisted wire, it rotates towards equilibrium, overshoots, then twists back in the opposite direction and so on. This is given by:

$$T = 2\pi\sqrt{I/\kappa} \qquad (4)$$

We can work out the moment of inertia of the stiff pendulum through comparing it with an object with known value of *I*, and rearranging using ratios. Subsequently, we can determine our value of *g* through substituting values into equation (2) through the following further steps.

$$\frac{T_P}{T_R} = \sqrt{\frac{I_P}{I_R}},$$

(5): *comparing the ratios*

$$I_P = I_R\left(\frac{T_P}{T_R}\right)^2$$

(6): *rearranging for I_p*

The moment of inertia for a thin cylindrical rod of length *L* and radius *r,* where the mass of the rod is given by M_R is also given by the following (7):

$$I_R = \frac{1}{12}M_R L^2$$

Using the *parallel axis theorem*, we can ascertain that $I_{||} = I_{C.O.M} + Md^2$ (8), where *M* is the mass of the body and *d* gives the perpendicular distance between the CoM axis and the new || axis.

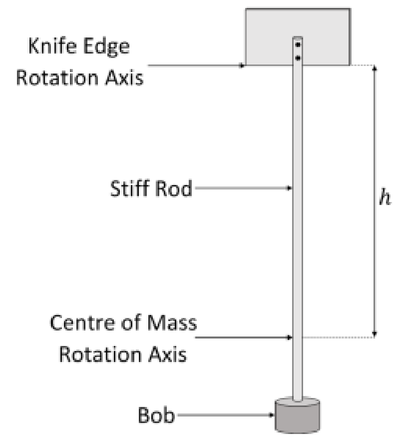
$$I = I_P + Mh^2$$

The experimental value of *g* is thus easily calculable from here.

Description of Set Up

Using diagrams and sketches, describe the setup of the experiment. Make it clear which parts are stationary and which parts will be moving.

The first half of the experiment concerned the time taken by a single oscillation. A pendulum bob is joined with a stiff rod and connected to a knife edge, from which it can rotate. Then, the knife edge is set up onto a horizontal surface *(i.e. a table)* and an oscillation of small angle (< 10°, in order for the small angle approximation to hold) is generated by releasing the pendulum bob at the appropriate height. Side: *Figure 2:* **the set-up of the stiff pendulum in the experiment.**



The second half of the experiment concerned calculating the moment of inertia, which represents the difficulty at which an object rotates around a given axis, and allowed for the attainment of a value for the *moment of inertia*, I.

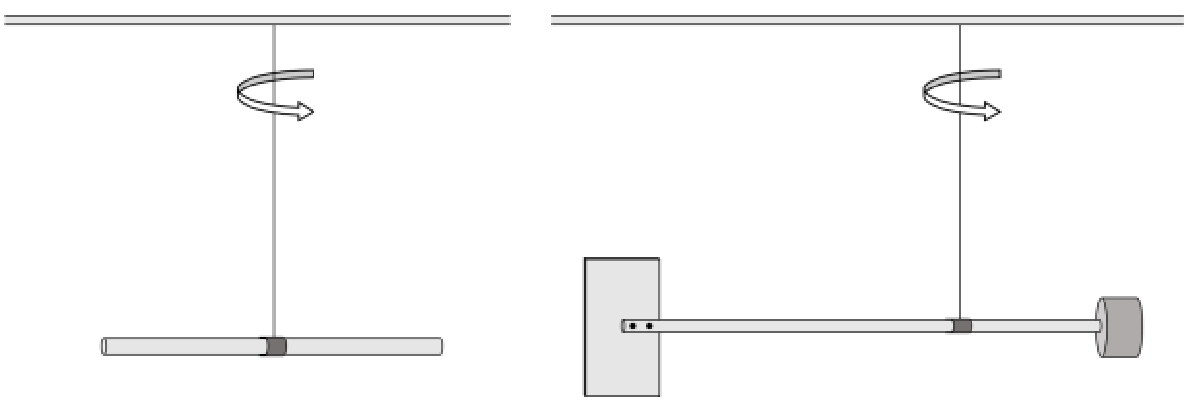


Figure 3: **the set-up for calculating the moment of inertia of the unknown stiff pendulum *(Right)* through comparison with the rod of known value of *I (Left)*.**

The stiff pendulum and rod are both suspended (at different times) from the same piece of copper wire which is hanging off the side of a horizontal surface *(i.e. workbench)* from a clamp, with a fastening Jubilee clip to secure the straightened piece of wire. This piece of copper wire is then made to rotate through by a known angle. A stopwatch was set up in order to accurately record the times when the rod would start and finish oscillating.

Care was taken to ensure safe handling of the equipment, in particular the sharp knife edge as well as the pendulum bob. The area was cleared around where the rod and pendulum would be

spinning when suspended due to safety considerations, as well as preventing interference with the results for the moment of inertia calculation.

Measurement Strategy

Make rough measurements of the phase shift at various positions, explore the different methods suggested in the lab manual and decide on the method you will use to acquire the data.
Make sure that you document the method and the reasons that you decided on this strategy.

In order to reduce the percentage uncertainty, it was decided that 20 oscillations would be taken, and then divided by 20 in order to ascertain the individual oscillation length. Similarly, this was conducted for the torsional pendulum, but 5 oscillations were taken due to time constraints. Measurements were taken using a stopwatch, and a camera was recording when oscillations began and end to determine the exact length.

Phase Difference Data

We recommend you enter your data into Excel to allow plotting and analysis. You should copy and paste the data into here. Make sure you include information you will need for later analysis (e.g. the frequency that the signal generator is set to).

Stiff Pendulum

Time Period of 20 Oscillations (20T) / s	Mean Time Period of 1 Oscillation (T) / s
34.23	1.712
34.13	1.707
34.26	1.713
34.39	1.720
34.22	1.711
34.36	1.718
34.23	1.712
34.11	1.706
34.18	1.709
34.29	1.715
34.11	1.706
34.21	1.711

34.24	1.712
34.14	1.707
34.15	1.708

Torsional Pendulum

Standard Rod		
Time Period of 5 Oscillations / s	Mean Time Period of 1 Oscillation /s	
58.39	11.678	
59.84	11.968	
59.77	11.954	
59.67	11.934	
59.75	11.950	

Pendulum Bob		
Time Period of 5 Oscillations	Time Period of 5 Oscillations / s	Mean Time Period of 1 Oscillation (T) /s
2.36.24	156.240	31.248
2.38.39	158.390	31.678
2.33.48	153.480	30.696
2.33.15	153.150	30.63
2.31.61	151.610	30.322

Phase Difference: Sources of Uncertainty

Note down the various sources of uncertainty and their values in this section.

Length of rod / m	0.79	0.001
Distance between centre of mass of pendulum and knife edge (h) / m	0.532	0.001
Total mass of cylindrical rod / kg	0.26962	0.00001
Total mass of the pendulum (M) / kg	0.56108	0.00001

Mass of copper wire / kg	0.00296	0.00001

Data Analysis

Use this section to record the process and outcome of your data analysis

Summary

Briefly summarise the main outcomes of the experiment

Our experimental value of the *g* differed significantly from the accepted value of 9.81ms^2, due to our calculation of g being 11.45±1.2 ms^{-2}. Even considering the lower bound of uncertainty from our calculated value (i.e. 10.2ms^{-2}), we were still off by about 0.4ms^{-2} from what we expected.

Upon further consideration, the heater blowing hot air which was above our workstation is very likely to have influenced the results that we obtained, by creating a breeze.