A simple pendulum and random errors

Instructions

1 Hang a simple pendulum (small mass, light string) from a rigid support.

2 Use your telephone stopwatch to find the period (the time for one swing), ten times.

If you have not done so please open the link and read *Reaction Time* [pdf]

3 Write down the average of the ten period values and find the likely error in three ways.

i Half the range.

ii The average deviation.

iii The standard deviation.

4 Time ten swings of the same pendulum *once* with the same stopwatch.

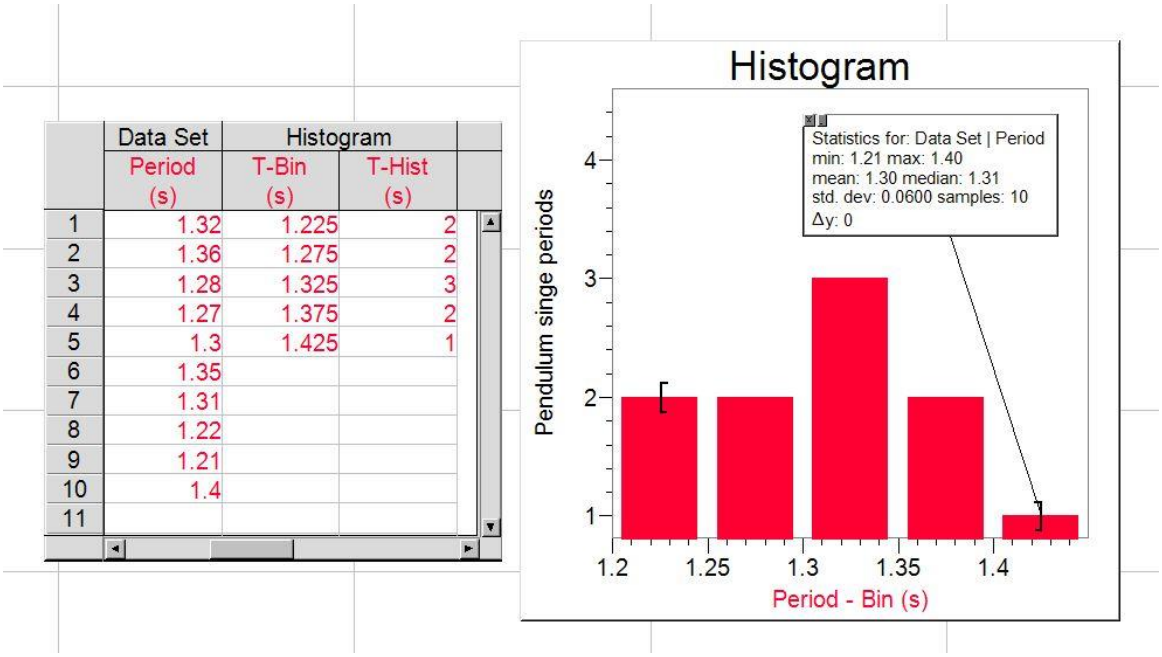
5 Write down the period of the pendulum with a likely error using only this single value of the time for ten periods. *Explain how you estimated the likely error*.

Solutions

1 A pendulum is shown with the string firmly taped to the bench top.

Fig 1 – a simple pendulum and a telephone-based stopwatch.

2 The period is measured carefully by hand ten times. The times are entered as manual data into Logger Pro. A histogram is plotted and the standard deviation is found.



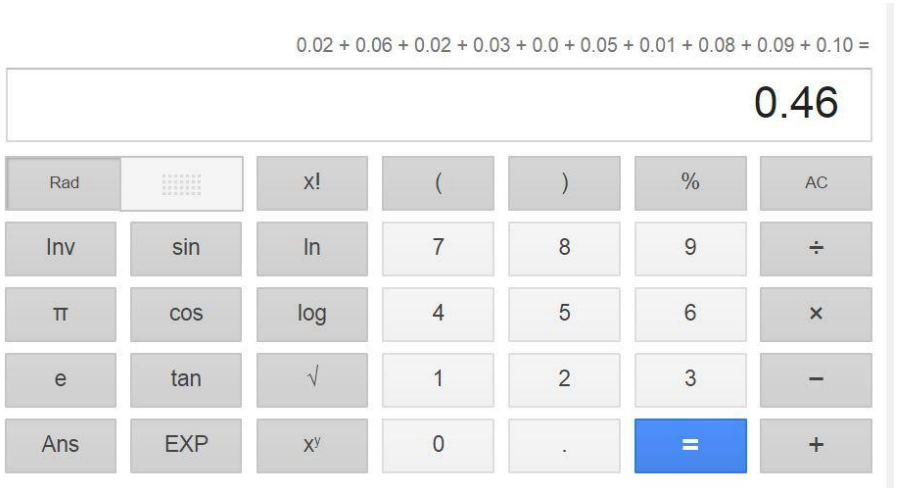
	Data Set	Histogram	
	Period (s)	T-Bin (s)	T-Hist (s)
1	1.32	1.225	2
2	1.36	1.275	2
3	1.28	1.325	3
4	1.27	1.375	2
5	1.3	1.425	1
6	1.35		
7	1.31		
8	1.22		
9	1.21		
10	1.4		
11			

Fig 2 – period data, distribution and standard deviation.

3 The sample is small (10 values) but the mean and median are almost the same, as expected for a normal distribution.

i The period is 1.3 ± 0.1 s ……. where the error is half the range.

ii The period is 1.30 ± 0.05 s … where the error is the average deviation found by adding the deviations**,** dividing by 10, and rounding to one significant figure.



iii The period is 1.30 ± 0.06 s … where the error is the standard deviation

4 The time for ten swings was measured (once) as 13.04 s.

5 The period of the pendulum (dividing by 10) is 1.30 ± 0.01 s.

Explanation

The error in a time measurement is the sum of the uncertainties in starting and stopping the watch. This error will be the same for measurements of one swing or ten swings. Half the range will be about 0.1 seconds in each case. Dividing by 10 will reduce half the range for the period measurement to 0.01 s when ten swings are timed.

Because only one value for ten swings was found (following the instructions) half the likely range has been used as the error. If ten periods were measured ten times, and the period was found as the average of these ten values, the smaller standard deviation should be used as the likely error.

The period would then be 1.300 ± 0.006 s.

Students may like to confirm this for themselves by taking measurements.

Questions

1 From your experience (above) why do the instructions for all pendulum labs in junior physics class ask for ten periods to be measured.

2 When students are asked to investigate the truth or otherwise of the simple pendulum period formula, they are always told to use small amplitude swings.

a Why are they asked to use small amplitudes?

b Why do these instructions not ask for small amplitudes (assuming a student will swing the pendulum the same way each time)?

3* The average person's reaction time to a visual stimulus is close to 0.2 s. Why are random errors in the times in the table in figure 2 very much less than 0.4 s?

4 The telephone-based digital stopwatch in figure 1 has a lap-time facility. If the lap-time button is hit at the end of each successive swing the times for ten swings can be recorded in one sequence.

a* Would period measurements made in this way be independent?

b* Would using the lap-time method be likely to reduce errors in the individual period estimates?