1. Experimental Contents

1) Measure the relationship between period of pendulum and angle of swing. Take extrapolation to acquire period at zero angle. Determine gravitational acceleration.
2) Measure period with a fixed pendulum length. Calculate gravitational acceleration. Or, gradually change pendulum length to measure the corresponding period. Determine gravitational acceleration by linear fitting. Verify the relationship of pendulum length is proportional to the square of period.

2. Experimental Procedures

1) Determine the relationship between swing angle and pendulum period. Plot graph of $2T \sim \sin^2(\theta/2)$. Derive gravitational acceleration *g*.

   a. Attach the small magnet to the bottom of the metal ball.

   b. Do not attach the Hall sensor onto the mirror at this stage. Let the string of the static pendulum act as the plumb-line. Adjust the height of the mirror which is attached to the support post carefully to make sure the hanging point of the ball and its image in the mirror intersects with the horizontal mark line on the mirror.

   c. Record the position of the horizontal mark line on the ruler of the post, it is string length L_1.

   d. Attach the Hall sensor onto the mirror, change the height of the mirror-Hall sensor assembly on the post until the Hall sensor is below the ball within a distance of 10 mm, so that the magnetic field of the magnet can be sensed by the Hall sensor.

   e. Adjust the counter/timer. Preset counting number.

   f. Pull the pendulum ball aside at a certain distance. Read the angle of the string from the protractor (make sure to eliminate parallax effect).

   g. Release the ball to let the ball swing in the vertical plane of containing the sensor.

   h. Measure the time of two periods using the timer. Due to the inconsistency of ball releasing, multiple measurements should be taken at the same angle to derive an average value.

   i. Change angle, and repeat the experiment.

j. Plot graph of $2T-\sin^2(\theta_m/2)$, derive gravitational acceleration *g*, and compare it with the theoretical value.

2) Validate the relationship between pendulum length and period, calculate gravitational acceleration *g*.

a. Change string length of pendulum.

b. Let swing angle $\theta < 3^{\circ}$, measure pendulum period under different lengths.

Note: each time after changing the pendulum length, follow steps a to h of the previous experiment to measure pendulum period of corresponding length.

c. Plot graph of T^2-L, derive gravitational acceleration *g*, and compare it with the theoretical value.

3. Examples of Data Recording and Processing

Note: the following data are for reference purposes only, not the criteria for apparatus performance.

1) Determine *g* by changing swing angle at fixed pendulum length

String length L_1=600 mm, Radius of ball *r*=10 mm.

Total pendulum length $L=L_1+r$=610 mm=0.610 m

Table 1 Measured data of θ and $2T$ at a fixed pendulum length

θ	$\sin^2(\theta/2)$	$2T$ (s)					
		1	2	3	4	5	Average
5°	0.00190	3.139	3.139	3.139	3.140	3.140	3.139
10°	0.00760	3.144	3.145	3.144	3.144	3.144	3.144
15°	0.01704	3.152	3.151	3.151	3.150	3.149	3.151
20°	0.03015	3.159	3.160	3.159	3.159	3.158	3.159
25°	0.04685	3.173	3.171	3.172	3.170	3.173	3.172
30°	0.06699	3.187	3.185	3.184	3.184	3.187	3.185
35°	0.09042	3.209	3.208	3.212	3.210	3.209	3.209
40°	0.11698	3.226	3.227	3.226	3.223	3.224	3.225

Based on the data shown in Table 1, a graph of $2T-\sin^2(\theta/2)$ is plotted as shown in Figure 2; by taking linear fitting, we get intercept $A=2T_0$=3.137 s and therefore the period at zero swing angle (0°) is T_0=1.569 s. By substituting T_0=1.569 s and $\theta_m = 0$ into (5), we get: g=9.782 m/s^2.

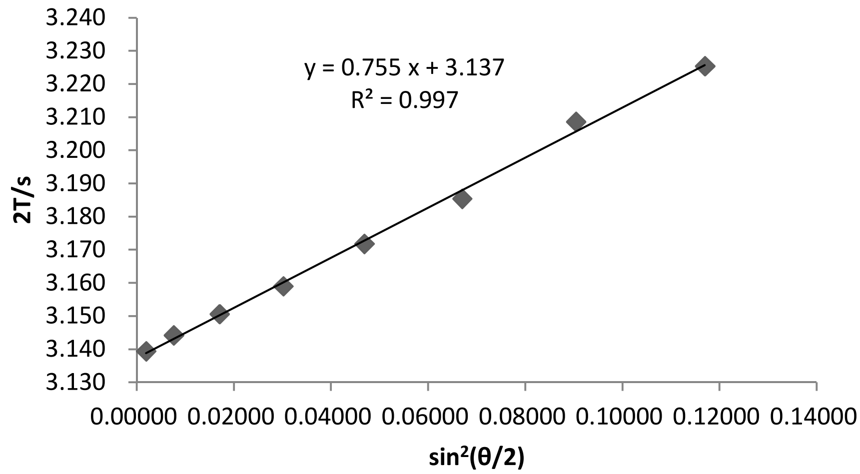

Figure 2 Relationship graph of $2T - \sin^2(\theta/2)$

2) Determine *g* by changing pendulum length

Table 2 Measured data of *T* by changing pendulum length *L*

L (m)	T (s)						T² (s²)
	1	2	3	4	5	Average	
0.310	1.123	1.118	1.120	1.120	1.119	1.120	1.254
0.360	1.202	1.202	1.205	1.201	1.204	1.203	1.447
0.410	1.286	1.286	1.287	1.287	1.285	1.286	1.654
0.460	1.364	1.361	1.363	1.362	1.361	1.362	1.856
0.510	1.432	1.433	1.436	1.436	1.434	1.434	2.057
0.560	1.500	1.501	1.499	1.498	1.502	1.500	2.250
0.610	1.568	1.568	1.569	1.567	1.569	1.568	2.459

Based on the data shown in Table 2, a graph of $T^2 - L$ is plotted as shown in Figure 3; by doing linear fitting, we get slope B=4π^2/g=4.017 s^2/m. Further, we get g=9.828 m/s^2.

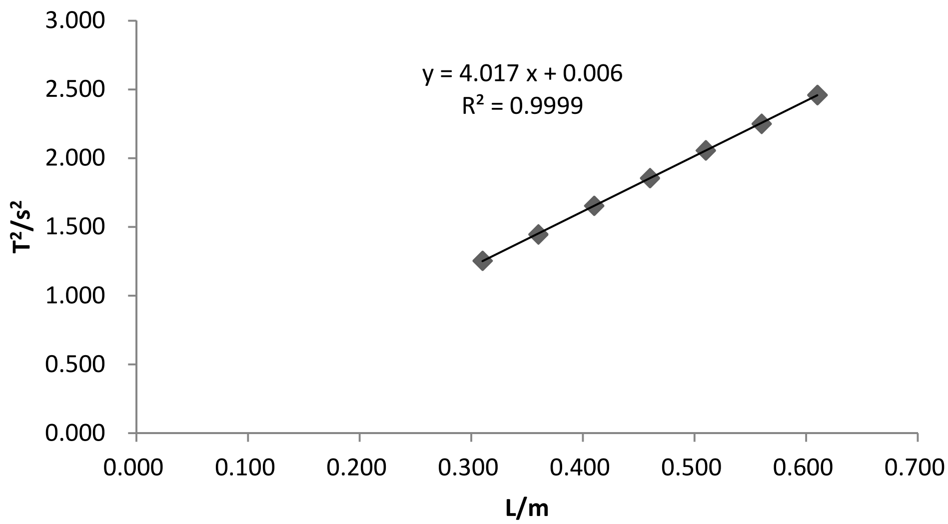

Figure 3 Relationship graph of $T^2 - L$

4. User Instruction of Timer

1. Working Principle

This instrument has timing and counting functions with a built-in microcontroller. It is triggered by the falling edge of the received signal. The indicator lamp blinks once for each received signal. After pre-setting the desired counting number, the instrument can start counting and timing from the 3rd received trigger signal (i.e. the first two trigger signals do not count). Upon receiving the next (4th) trigger signal, timing stops and counting is recorded as once, and the time interval is stored. Same for the following triggers, every two triggers will record a time interval until the pre-set counting number is reached. All time intervals are stored and can be viewed later.

2. Operation Instruction

   a) Connect the sensor to the instrument.
   b) Turn on power, pre-set counting number by pressing on “Set/View” button once and then using the “+” or “-” button. Now, the instrument is at a waiting state and the indication lamp is dim. For each trigger signal received, the lamp blinks once; after receiving 3 trigger signals, the counting and timing functions start to work.

When the counting number reaches the preset value, the time intervals for all adjacent triggers are stored and can be read out. Press “Set/View” button, these time intervals can be viewed.