Physics Laboratory Report

The number and the name of the experiment：Experiment 4－

Determinating of acceleration due to gravity by timing a simple pendulum

The date of experiment：18 / 1 / 08

Objective

- To investigate the relationship between the period and the distance of pendulum bob from the ground
- To measure the acceleration due to gravity from the experiment

Apparatus

- A piece of string at least one meter long
- retort stand and clamp
- stop-watch
- a pendulum bob
- g-clamp / heavy stuff(for fixing the stand)

- two coins
- a table
- a chair

The diagram of the setup

Procedure

1. Attach the pendulum bob to one end of the light string and nail the string to the coins, and place the coins onto the stand.

2. Set the pendulum bob to swing through a small arc of about 20^0
3. Measure the time for the bob to complete 20 oscillations.
4. Repeat the timing. Record the results in the table.
5. Change the value of d (the distance of the bob from the ground) stepwise using a step size of about 5cm. Repeat steps 1 to 3 for a total of 10 different lengths.

Precaution

- Start the stop watch and on the count of zero and stop it on the count of 20.

Explanation：When we loosen the hand which holds the bob through an angle about 20^0, the bob starts to oscillate, as it hasn't swing forward and back for once, so we should count it for the number "zero". And when it has swung back to the original position for the first time, we can start to count it for number "one". Finally, when it swung back to the same position for the twentieth time and we stop it on the count of 20.

- Make sure that the pendulum swing in a vertical plane.

Explanation：If the mass does not oscillate vertically, some of the kinetic energy will be wasted. And its displacement of oscillation can not be described by harmonic functions. Thus, the oscillation is not a simple harmonic motion.

- Count the oscillation when the bob reaches the most right-hand side or most left-hand side.

Explanation：As when the bob swung forward to the most right-hand side and swung back to the left-hand side, it can be said as a completed oscillation.

- Timing should be aborted if the oscillation of the pendulum bob becomes elliptical.

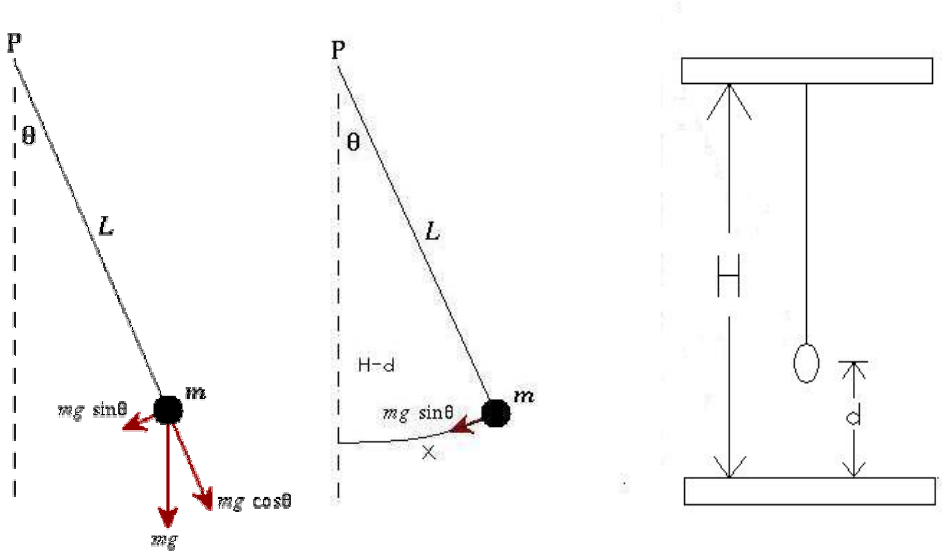
Explanation：As the bob must be swung in a vertical plane in order to obtain an accurate reading of corresponding period, if the oscillation of the pendulum bob becomes elliptical, the oscillation is not simple harmonic motion any more. Thus, the taking of the time becomes meaningless and the timing should be aborted and starts a new one.

Table of data

distance of the bob from the ground/m	Time for 20 oscillations					Period of oscillation T / s	$(Period)^2$ T^2 / s^2
	t1	t2	t3	t4	Mean t		
0.30	50.77	50.86	50.95	／	50.86	2.54	6.47
0.35	50.00	50.01	50.07	／	50.03	2.50	6.26
0.40	49.16	49.16	49.17	／	49.16	2.46	6.04
0.45	48.37	48.28	48.28	／	48.31	2.42	5.83
0.50	47.33	47.38	47.38	／	47.36	2.37	5.61
0.55	46.66	46.55	46.64	／	46.62	2.33	5.43
0.60	45.71	45.71	45.68	／	45.70	2.29	5.22
0.65	44.84	44.83	44.88	／	44.85	2.24	5.03

0.70	43.92	43.92	44.00	／	43.95	2.20	4.83
0.75	42.94	43.00	43.03	／	42.99	2.15	4.62

Theory



When the string makes an angle θ with the vertical, the displacement of the bob is the arc length given by x = (H-d) θ ……(1) and the restoring force acting on it is along the tangent, given by F = − mgsin θ ……(2). See Fig c, the net force causes the bob to accelerate towards the equilibrium position, given by F =

ma = $-$ mgsin θ ……(3). For small angle θ , we have sin $\theta \sim \frac{X}{H-d}$ ……(5).

Putting (5) into (3), we have ma $\sim -\frac{mg}{H-d}$ X, or a = $-\frac{g}{H-d}$ X……(6) for small

amplitude. Hence the motion is simple harmonic and the period is $T = 2\pi\sqrt{\frac{H-d}{g}}$.

By taking square on the both side, $T^2 = \frac{4\pi^2}{g}$ (H-d)……$T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}H$,

Where $-\frac{4\pi^2}{g}$ is the slope and $\frac{4\pi^2}{g}$ H is the y-intercept.

Calculation

The slope m = $\frac{6.50-4.83}{0.29-0.70} = -4.07$

$\because$ Slope = $-\frac{4\pi^2}{g}$ $\therefore$ Acceleration due to gravity (g) = $\frac{-4\pi^2}{-4.07} = 9.69$

The maximum slope $m^+ = \frac{6.40-4.80}{0.32-0.70} = -4.21$

The maximum slope $m^- = \frac{6.15-4.85}{0.325-0.74} = -3.13$

$|m^+ - m| = 0.137$

$|m^- - m| = 0.940$

$\therefore$ The maximum error in slope $\triangle m = 0.940$

Percentage error in slope = $\left|\frac{\triangle m}{m} \times 100\%\right|$

$= \left|\frac{0.940}{-4.073} \times 100\%\right|$

$= 23.1\%$

The maximum error in g = 9.69 $\times$ 23.1% = 2.24

$\therefore$ The acceleration due to gravity g = 9.69 $\pm$ 2.24

An interpretation of the results

The value of g reflects the reality of the errors appeared in the experiment. We can

see that the maximum possible error is really large, thus, it affects the expression of the answer which is inaccurate. On the other hand, I gain some experiences from obtaining the value of the maximum possible error, that is we need to be absolutely concentrated to each set of the data we take, and pay attention to every timing as any one of the timing which is carelessly taken will influence the slope of the line at the graph. Finally, it causes the serious inaccuracy

Discussion

1. Discuss the difficulties and limitation of the experiment

Ans：It is difficult to take the time of oscillation accurately / It is impossible for the man to use hand so as to let the pendulum swing in a vertical plane / the string used must be at least one meter long

2. The sources of errors in the experiment

Ans：The pendulum does not oscillate exactly in vertical plane / The reaction time of the observer when he starts timing for beginning and the stopping of the oscillation will cause the human error and lead to the inaccurate reading of time / there exists friction where the string is nailed to the coins and affects the mechanical energy of the pendulum bob system.

3. Suggest improvement to the experiment

Ans：Using motion sensor rather than timer to record the oscillation of pendulum bob which is the simple harmonic motion

4. Discuss how the value of H can be determined

Ans：By the equation $T^2 = \frac{4\pi^2}{g}$ (H-d), we know the value of T^2,$\frac{4\pi^2}{g}$ and d, so we can solve the value of H.

Conclusion

From the experiment, we obtain that the acceleration due to gravity (g) is 9.69 ± 2.24, the period of the oscillations of the pendulum varies inversely as the distance of the pendulum bob from the ground. It is very difficult to carry out the mechanical experiment accurately as many errors must be existed.