Experiment 7-1. physical pendulum

1. Purpose

Observe the motion of an object that performs periodic motion in relation to rotational motion and measure the vibration period to obtain the gravitational acceleration g.

2. Theory

Unlike a simple pendulum, an actual pendulum has a complex mass distribution and is called a physical pendulum. Figure 1 shows a physical pendulum tilted to one side by an angle.

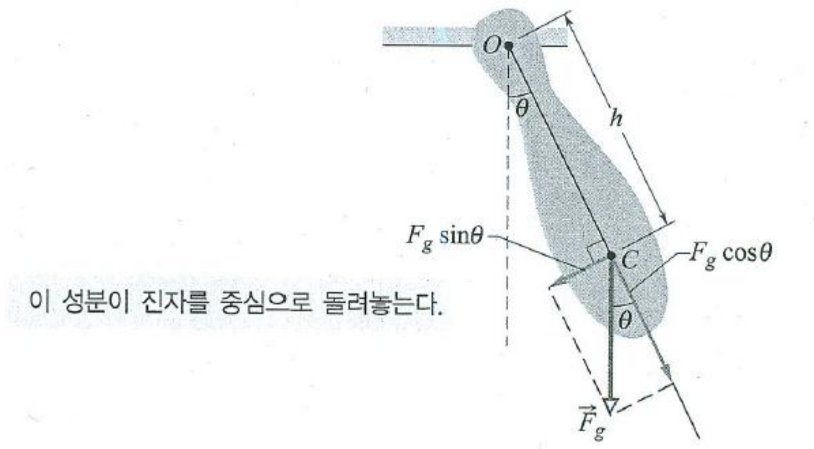


그림1. 물리진자

Gravity $\vec{F}_g$ acts on the center of mass C, which is a distance h from the hanging point O. Although they have different shapes, there is only one major difference between a simple pendulum and a physical pendulum. In the case of a physical pendulum, the moment arm for the restoring force $F_g \sin\theta$ is not the length of the string L like a simple pendulum, but the distance h from the hanging point to the center of mass. For all other points, the same method used to analyze the motion of a simple pendulum can be used. Therefore, even in the case of a physical pendulum, if the angular amplitude θ_m is small, it can be treated as a simple harmonic motion as a rule of thumb. At this time, the period T of the physical pendulum is as follows.

$$T = 2\pi\sqrt{\frac{I}{mgh}} \tag{1}$$

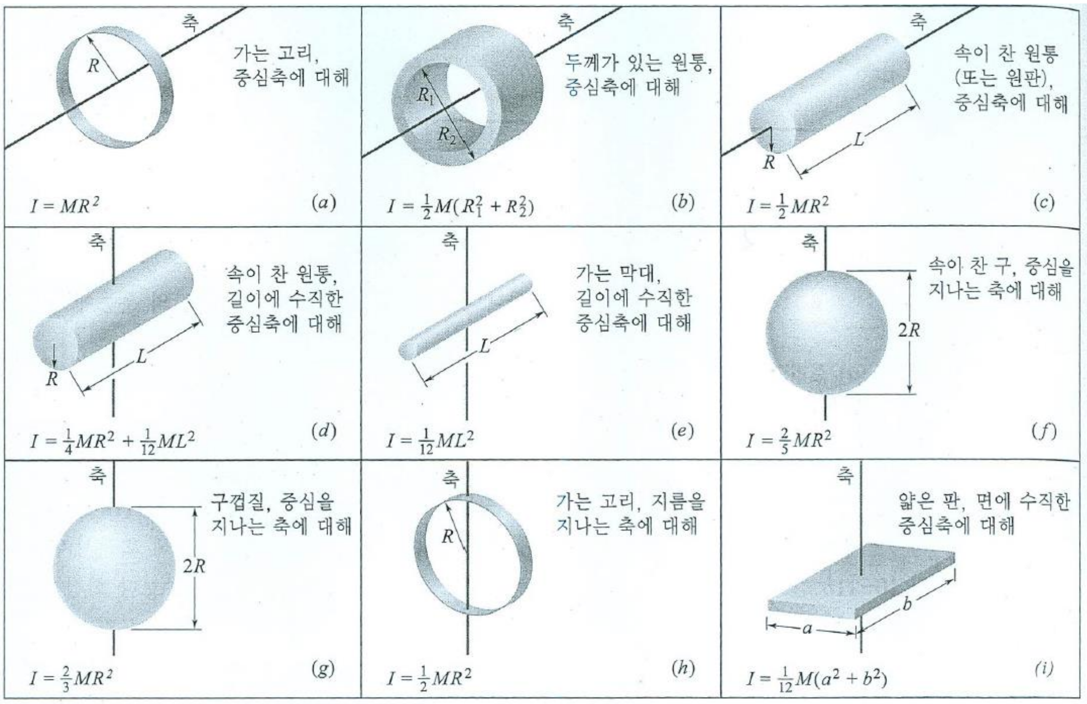


그림2. 여러 물체의 회전관성모멘트

Figure 2 shows the rotational moments of inertia of nine commonly seen objects. The moment of inertia about the center of mass of the rectangular plate-shaped rigid body is $I = (1/12)\mathrm{M}(\mathrm{a}^2 + \mathrm{b}^2)$ in Figure 2(i). At this time, in the case of $a << b(=\mathrm{L})$, it approximately becomes $I = (1/12)\mathrm{ML}^2$ as shown in Figure 2(e). However, all objects can have countless moments of inertia because they can rotate around an arbitrary axis other than the center of mass. As shown in Figure 3, when an object of mass M rotates around an arbitrary axis, the moment of inertia I' can be expressed as follows using the parallel axis theorem.

$$I' = I + Mh^2 \tag{2}$$

Therefore, the period T of a bar-shaped physical pendulum of length L can be obtained from equations (1) and (2) as follows.

$$T = 2\pi\sqrt{\frac{L^2 + 12h^2}{12gh}} \tag{3}$$

3. Instruments and devices

기구와 장치	Equipment	수량	비고

로터리모션센서	rotary motion sensor	1
850 인터페이스	850 Interface	1
막대 진자	pendulum(rod)	1
미터자	1m	1

4. Experiment method

caution	
caution	– When the physical pendulum moves, be careful not to let the wire interfere with the movement of the pendulum. – Continue recording until the physical pendulum vibrates sufficiently.

Install the rotary motion sensor and physical pendulum as shown in Figure 3

Figure 3. Physical pendulum installation

(1) Connect the rotary motion sensor to PASCO Capstone and set as shown in Figure 4.

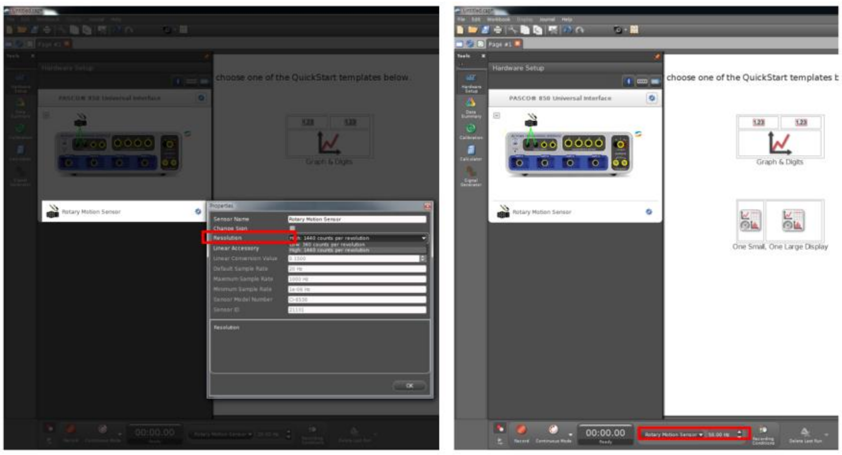


Figure 4. Data Studio settings

(Resolution: High, Sample rate: 50Hz)

(2) After pressing the Record button on the PASCO Capstone, vibrate the physical pendulum and record the results. At this time, the appropriate vibration angle of the physical pendulum is 5 to 10 degrees. (Recordings should be kept until the shaking almost stops.)

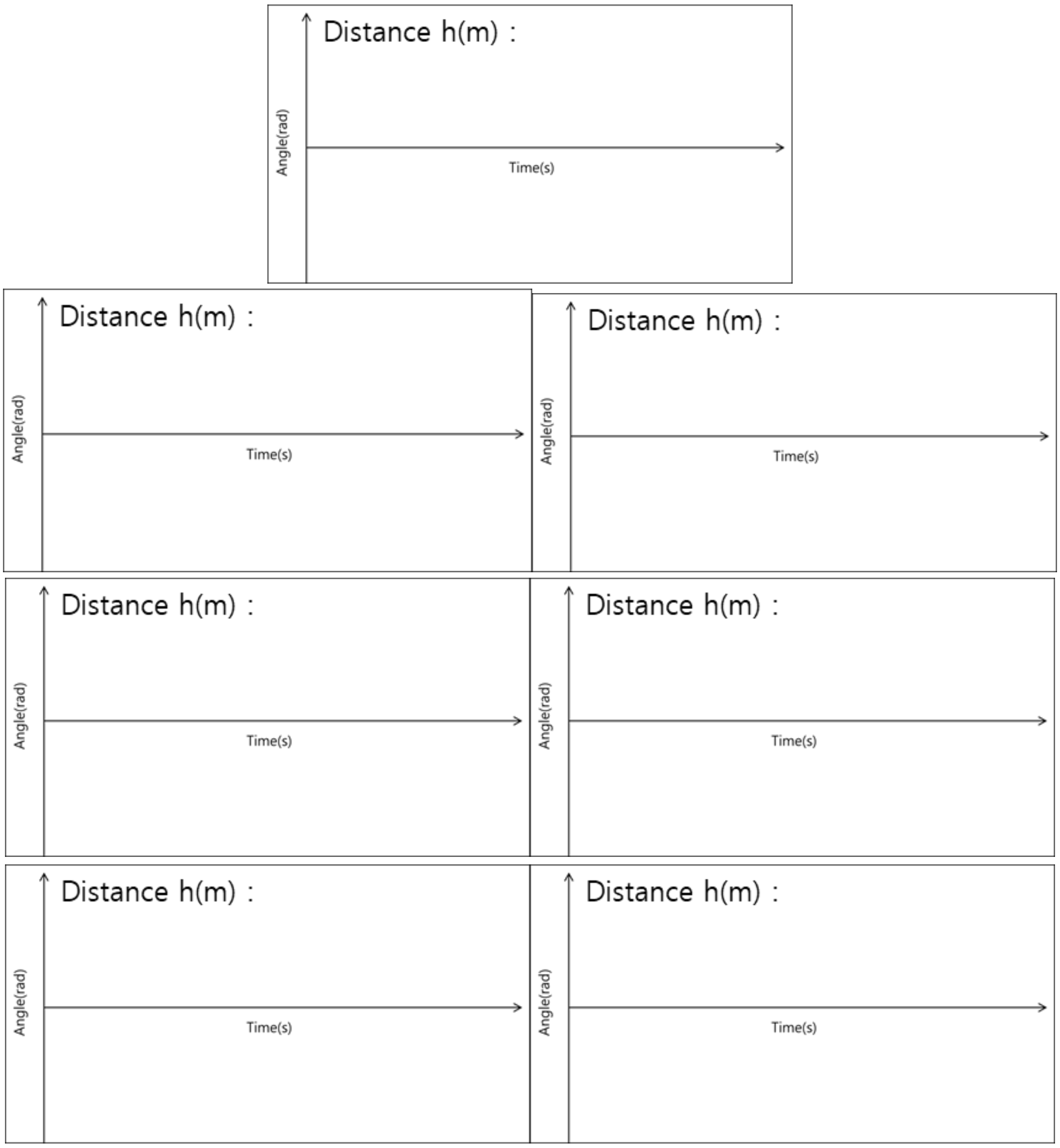
(3) Repeat the measurement by changing the distance between the rotation axis and the center of gravity of the physical pendulum and record the results.

(4) When the physical pendulum oscillates within 5 degrees (approximately 0.087 rad), record the average period of 10 (or more) oscillations in a table.

(5) After completing the recording and experiment, organize the experiment tools.

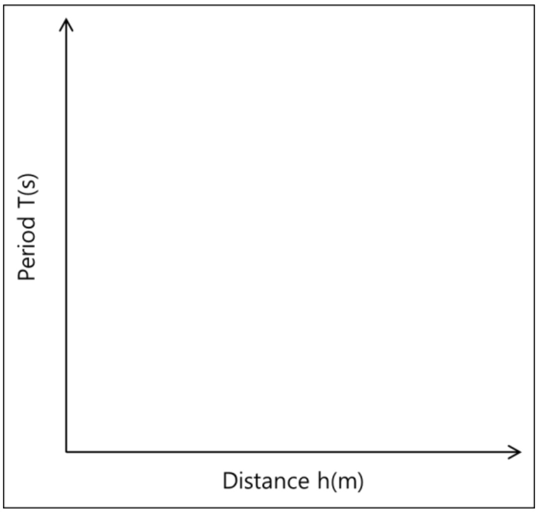
5. Physical pendulum experiment DATA SHEET

Rod length (m):



Distance h (m) vs period (s)

Distance h (m)	Period (s)			Gravitational acceleration (m/s^2)	
	exp	theory	error (%)	exp	error (%)



6. Question

(1) What is the difference between a simple pendulum and a physical pendulum?

(2) What is the relationship between the distance (h) and period (s) between the center of mass and the axis of rotation of a physical pendulum?

(3) At what point is the distance (h) between the center of mass of the physical pendulum and the axis of rotation where the period is minimum?

7. References

Halliday, Resnick, Walker, (2014), PRINCIPLES OF PHYSICS, WILEY

Experiment 7-2. Free fall motion experiment

1. Purpose

By dropping a picket fence between photogates, a speed-time graph of free fall motion is obtained. Obtain the gravitational acceleration g value from the slope of the graph and compare it with the theoretical value.

2. Theory

The equation of motion starting from a stationary state is $x = \frac{at^2}{2}$ (x : distance, a : acceleration, t : elapsed time)

3. Instruments and devices

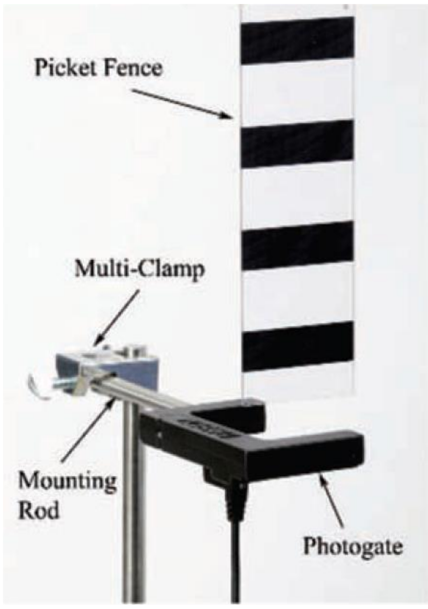
기구와 장치	Equipment	수량	비고
850 인터페이스	850 Interface	1	
포토게이트 헤드	Photogate Head	1	
멀티 클램프	Multi Clamp	1	
마운팅 로드	Mounting Rod	1	
피켓 펜스	Picket Fence	1	

4. Experimental method

A. Experimental equipment setup

1. Install the photogate on the stand as shown in the following picture, then adjust the angle of the photogate so that it is parallel to the floor.
   Note: Place a sponge, etc. at the drop point of the picket fence to prevent the picket fence from being damaged.

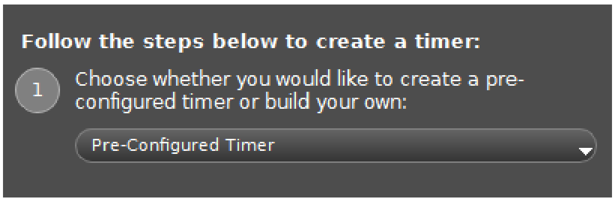
2. Connect the photogate to the digital terminal of the interface.



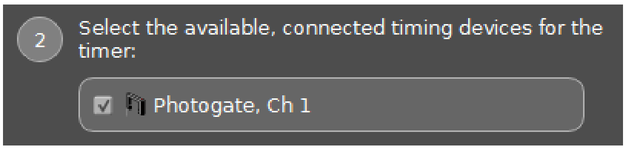
3. Open the 'Hardware Setup' window in Capstone software and click the terminal of the interface where the photogate is connected. Select Photogate from the drop-down list. A photogate icon will be displayed on the corresponding terminal.

B. Photogate settings

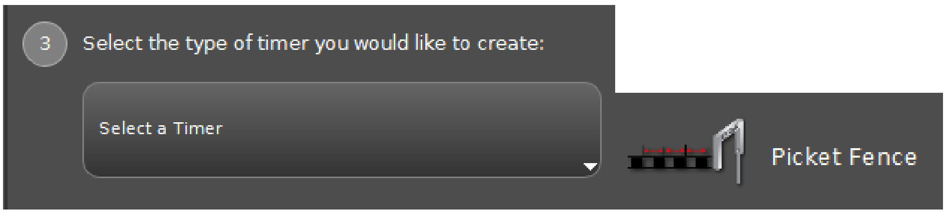
1. When you open the 'Timer Setup' window, the <New Timer> configuration wizard starts. In the first step, select the Pre-Configured Timer item.



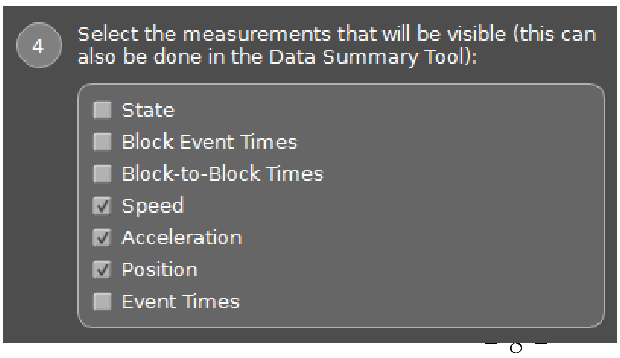
2. Check whether the photogate channel is correctly assigned.



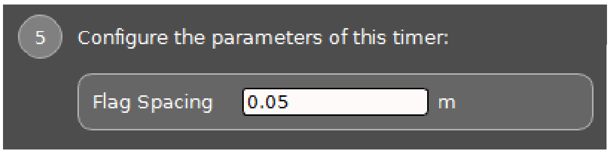
3. Click the white arrow under the Select a Timer tab, then click 'Picket Fence' from the list.

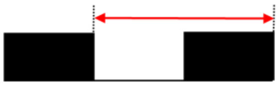


4. Select all measurements you want to display.

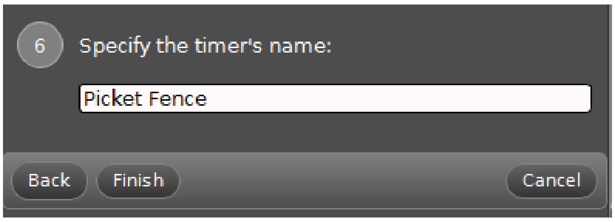


5. Enter the spacing between fences.





6. Enter a name for the timer, then click the Finish button to save the timer settings.



C.실험 방법

1. Add a graph display in Capstone software and then construct a speed-time graph.

2. Click the Record button to start collecting data. Drop the picket fence between the photo gates. Click the Stop button to stop data collection.

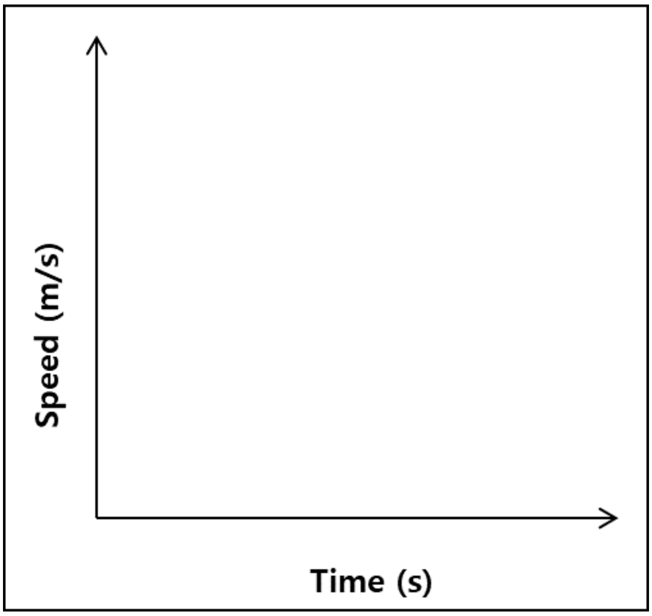
3. Apply Linear Fit in the graph tool to find the slope (acceleration) of the graph.

4. Repeat the measurement 10 times to obtain the average value of acceleration.

5. Experiment result

speed over time

Time (s)	Speed (m/s)



acceleration of gravity

	중력가속도 g (m/s^2)		중력가속도 g (m/s^2)
1		6	
2		7	
3		8	
4		9	
5		10	
Min			
Max			
mean			
error (%)			

6. question

- Is the gravitational acceleration obtained through experiments at the equator the same as the gravitational acceleration measured at the North Pole? Why? (hint: The equatorial radius is longer than the polar radius.)

- Student A dropped an object from the roof of the 63 Building to conduct a free fall motion experiment. Does speed increase infinitely? Why?

- Explain why satellites do not fall to the Earth's surface.