

Practical Work 4

Reversible Pendulum

(Study of Gravity)

1. Objective

To measure the acceleration due to gravity g using a reversible (Kater's) pendulum.

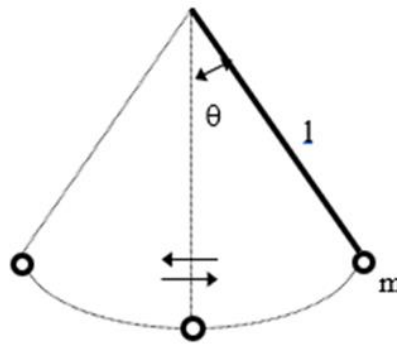
2. Theory

2.1 Simple Pendulum

A simple pendulum consists of a mass m suspended by a massless string of length l , oscillating in a vertical plane. For small angular displacements (θ), all oscillations have the same period T , given by:

$$T = 2\pi \sqrt{\frac{L}{g}} \dots\dots (1).$$

Where g is the gravitational acceleration. The period is independent of the mass, and air resistance is neglected.

**Figure 1**

2.2 Compound Pendulum

A compound pendulum is a rigid body that can oscillate freely about a horizontal axis (yy') under its own weight (Figure. 2). Let O be the suspension point, G the center of mass, d the distance OG , m the mass, and J the moment of inertia about yy' . Assuming small oscillations, the period is given by:

$$T = 2\pi \sqrt{\frac{J}{mgd}} \dots \dots \dots (2).$$

Using $J = mk^2$, where k is the radius of gyration:

$$T = 2\pi \sqrt{\frac{k^2}{gd}} \dots \dots \dots (3).$$

By comparing Eqs. (1), (2), and (3), we see that the compound pendulum behaves like a simple pendulum with an equivalent length:

$$I = \frac{J}{md} = \frac{K^2}{d} \dots \dots \dots (4).$$

This l is called the reduced length of the compound pendulum. If the pendulum is suspended from a point at distance l from O , it oscillates with the same period.

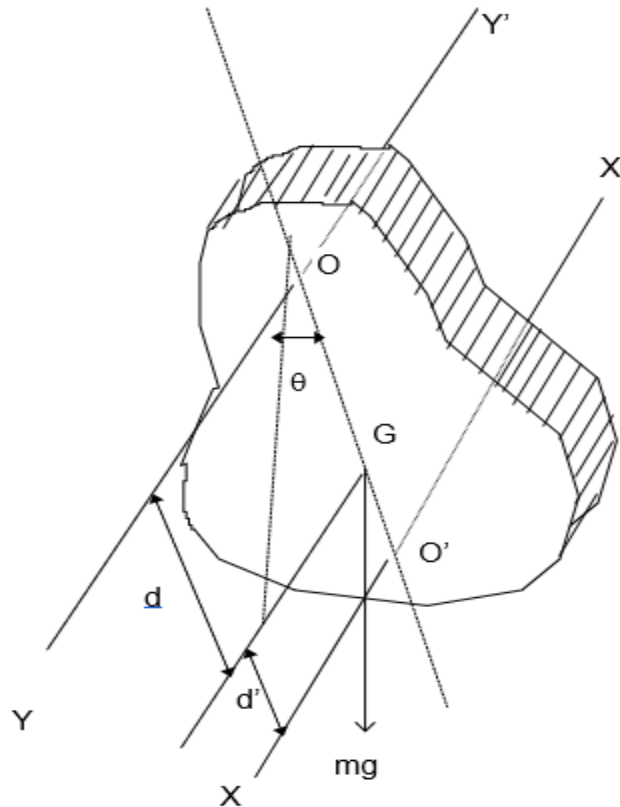


Figure 1

2.3 Reversible (Kater's) Pendulum

The Kater's pendulum (Figure. 3) is a type of compound pendulum composed of four sliding masses (A, B, C, and M) on a graduated bar. Two sharp knife-edges (A and B) act as pivot points (xx' and yy'). Three masses (A, B, C) remain

fixed, while the fourth mass M is adjustable to modify the period.

By varying M , the following relations can be plotted:

$T_{xx'} = f(d)$ and $T_{yy'} = f(d)$. The reversible points are found when $T_{xx'} = T_{yy'}$. At this point, with known l and T , g can be calculated using Eq. (1):

$$g = 4\pi^2 \frac{l}{T^2} \dots\dots\dots (4').$$

Error Estimation

Relative error: $\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2 \frac{\Delta T}{T} \dots\dots\dots (5).$

Absolute error: $\Delta g = g_{mes} \left(\frac{\Delta l}{l} + \frac{2\Delta T}{T} \right) \dots\dots\dots (6).$

Final value of g : $g = g_{mes} \pm \Delta g \dots\dots\dots (7).$

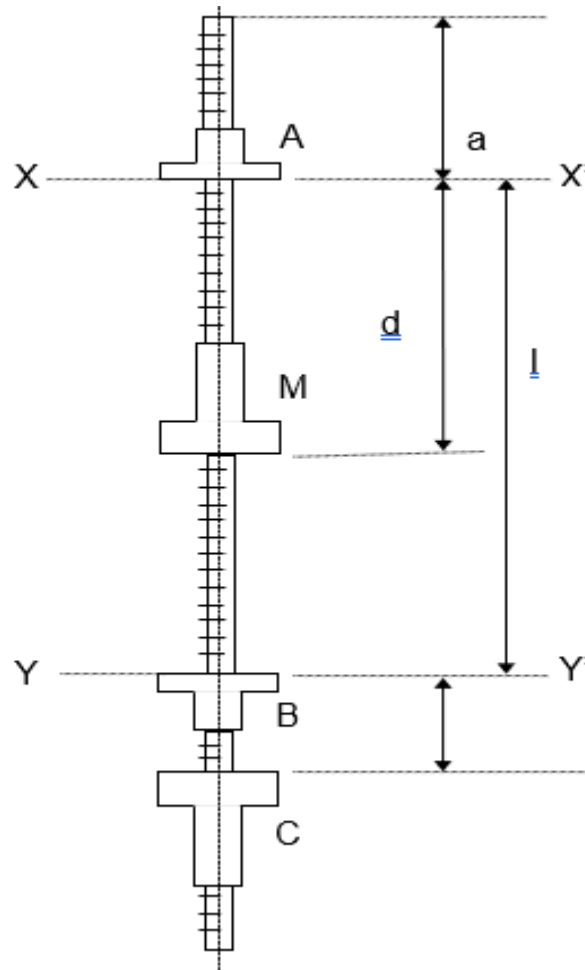


Figure 2

3. Experimental Procedure

Apparatus: Katter's reversible pendulum, Chronometer, Electrical contacts and wires, 5V photoelectric cell.

*The pendulum is mounted as shown in Figure. 3, with the electrical timing circuit connected as in Figure. 4.

Precautions include careful placement of knife-edges and proper sensor alignment.

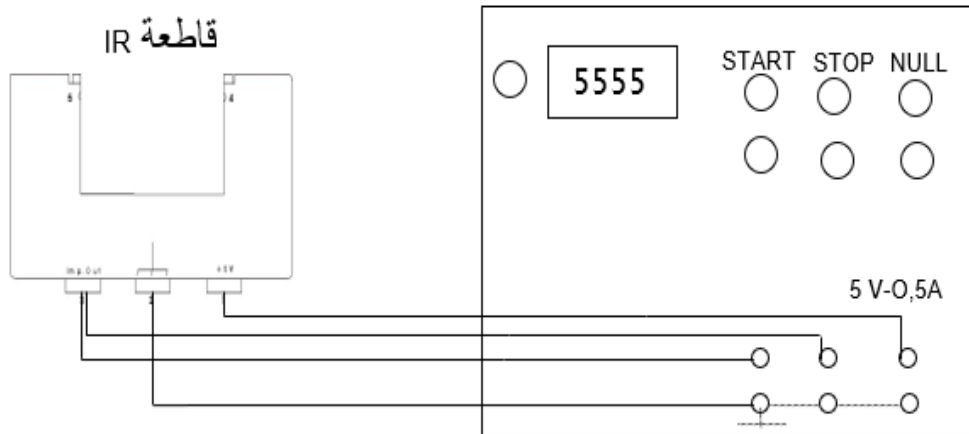


Figure 3

4. Notes and Precautions

- Keep the masses C, B, and A fixed according to Figure (3).
- The distance between B and A should be 58 cm, and distance a should be 21 cm. The mass C must be positioned as instructed by the supervisor so that BC equals 8, 9, 10, or 11 cm.
- Place the pendulum so that the sharp grooves (under supports A and B) rest on the knife-edges. It is recommended to place the pendulum carefully to avoid damaging the knife-edges.
- Set up the electrical circuit: connect the three terminals of the interrupters to the corresponding terminals of the

chronometer (see Fig. 4). Connect the chronometer to a 220V power supply.

- Align the interrupters vertically with the pendulum motion.

5. Measurements

1. Measure the time for 5 oscillations of the pendulum, taking at least 3 readings with a maximum deviation not exceeding 0.02 s. Estimate Δt and ΔT . The distance's d takes the values: 10, 15, 20, 25, 30, 35, 40, 45, and 50 cm.
2. Measure t_{xx}' , t_{yy}' , and deduce T_{xx}' and T_{yy}' .
3. Record the results in the following table:

$\Delta T_{yy'}$ (s)	$T_{yy'}$ (s)	$\Delta t_{yy'}$ (s)	$t_{yy'moy}$ (s)	$t_{yy'}$ (s)	$\Delta T_{xx'}$ (s)	$T_{xx'}$ (s)	$\Delta t_{xx'}$ (s)	$t_{xx'moy}$ (s)	$t_{xx'}$ (s)	(cm)
cal	cal	cal	cal	1	cal	cal	cal	cal	1	10
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	15
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	20
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	25
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	30
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	35
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	40
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	45
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	
cal	cal	cal	cal	1	cal	cal	cal	cal	1	50
≈	≈	≈	≈	2	≈	≈	≈	≈	2	
				3					3	
				4					4	
				5					5	

6. Questions:

- 1) Fill in the experimental results table after ensuring that there are no outliers.
- 2) Draw on the same millimeter paper the curves $T_{xx}'=f(d)$ and $T_{yy}'=f(d)$, knowing that...
- 3) The curves $T_{xx}'=f(d)$ and $T_{yy}'=f(d)$ intersect at points **A** (T_A, d_A) and **B** (T_B, d_B). Determine the average value of the period T_{moy} :
- 4) calculate the acceleration due to gravity and write the results in the form: $(g=g_m \pm \Delta g)$.
- 5) Compare the obtained result for g with the theoretical result, and conclude: Is there agreement between them? Justify your answer.