REPORT LAB 2

DETERMINING GRAVITATIONAL ACCELERATION WITH A REVERSIBLE PENDULUM

Class: CC10 / Group: 01	Lecturer's comment
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I. Aims/Purposes

Measuring the gravitational acceleration with a reversible pendulum.

II. Apparatus, Methods, and Procedure

1. Method:

Using the timer device(MC-963A) measure the time of 50 oscillation period. We can determine gravitational acceleration based on the equation.

2. Apparatus:

- Physical pendulum.
- MC-963A meter
- Optical infrared port.
- Pendulum suspension.
- Ruler 1000mm
- Caliper 0-150mm, accuracy 0.1 or 0.05mm
- Paper 120x80mm.

3. Procedure:

1. Turn on the Weighted C closed to the weights 4. Use the caliper to measure the distance x0 between them. Place the pendulum on the rack in the forward direction measuring the time of 50 oscillation period and recorded in Table 1, below the columns $50T_1$.

2. Reverse the pendulum, and measured the time of 50 oscillation period, recording the results in Table 1 below $50T_2$ column.

3. Set the location Weighted C to weights 4 away a distance x' = x_0 + 40mm. Measuring the period of 50 cycles and 50 reverse cycles with this position, recording the results in Table 1.

4. Performance of the measurement results on the graph. Connect the $50T_1$ and $50T_2$ points together by straight lines, their communication is the approximate location of x for $T_1 = T_2$ (H_3).

5. Use callipers to place the weight C on the right position x_1. Measured $50T_1$ and $50T_2$. Record results in table 1.

6. Adjust the weight C to the right position: Figure 4 shows the line 50 T_1 slope than the T_2. From the results of measurements 5, at x_1 we can conclude that to obtain the best results, we must shift direction the weight C so that $50T_1 = 50T_2$.

7. Finally, when the best location of Weighted C has identified, we measured each direction 3-5 times to get random error, Record results in Table 2.

8. Use a ruler (1000 m) to measure the distance L between the two blades O_1, O_2. Record in Table 1.

9. To complete the experiment, turn of the MC-963 meter and unplug it from the power of ~ 220V.

III. Equations

1. **Determine the period of oscillation of the reciprocating pendulum**:

• The period of oscillation T of the reciprocal pendulum is the average of the values measured value m:

$$\bar{T} = \frac{1}{50}\frac{(\overline{50T_1}+\overline{50T_2})}{2}\,(s)$$

• Random error of T measurement:

$$\overline{\Delta T} = \frac{1}{50}\frac{(\overline{\Delta 50T_1}+\overline{\Delta 50T_2})}{2}\,(s)$$

• Instrumental error of measurement T:

$$\Delta T = \frac{\Delta T_{clock}}{50}$$

• Measurement error T:

$$\Delta T = (\Delta T)_{dc} + \overline{\Delta T}$$

2. **Calculate the acceleration due to gravity:**

• Calculate the acceleration due to gravity:

$$\bar{g} = \frac{4\pi^2\bar{L}}{\bar{T}^2}\ (\frac{m}{s^2})$$

• Calculate the relative error of the acceleration due to gravity:

$$\delta\ = \frac{\Delta g}{\bar{g}} = 2\frac{\Delta\pi}{\pi} + \frac{\Delta L}{\bar{L}} + 2\frac{\Delta T}{\bar{T}}$$

• Calculate the absolute error of the acceleration due to gravity:

$$\Delta g\ = \delta.\overline{g}$$

3. **Write down the results of the measurement of the acceleration due to gravity:**

$$g\ =\ \bar{g} \pm\ \Delta g$$

IV. Experimental data

Table 1: L=700 ± 1(mm)

Weighted position (mm)	$50T_1$ (s)	$50T_2$ (s)
x_0 = 0 mm	83.35	83.77
x_0+40 = 40mm	84.19	84.07
x_1 = 20.02 mm	84.04	84.02

Graph the experimental data:

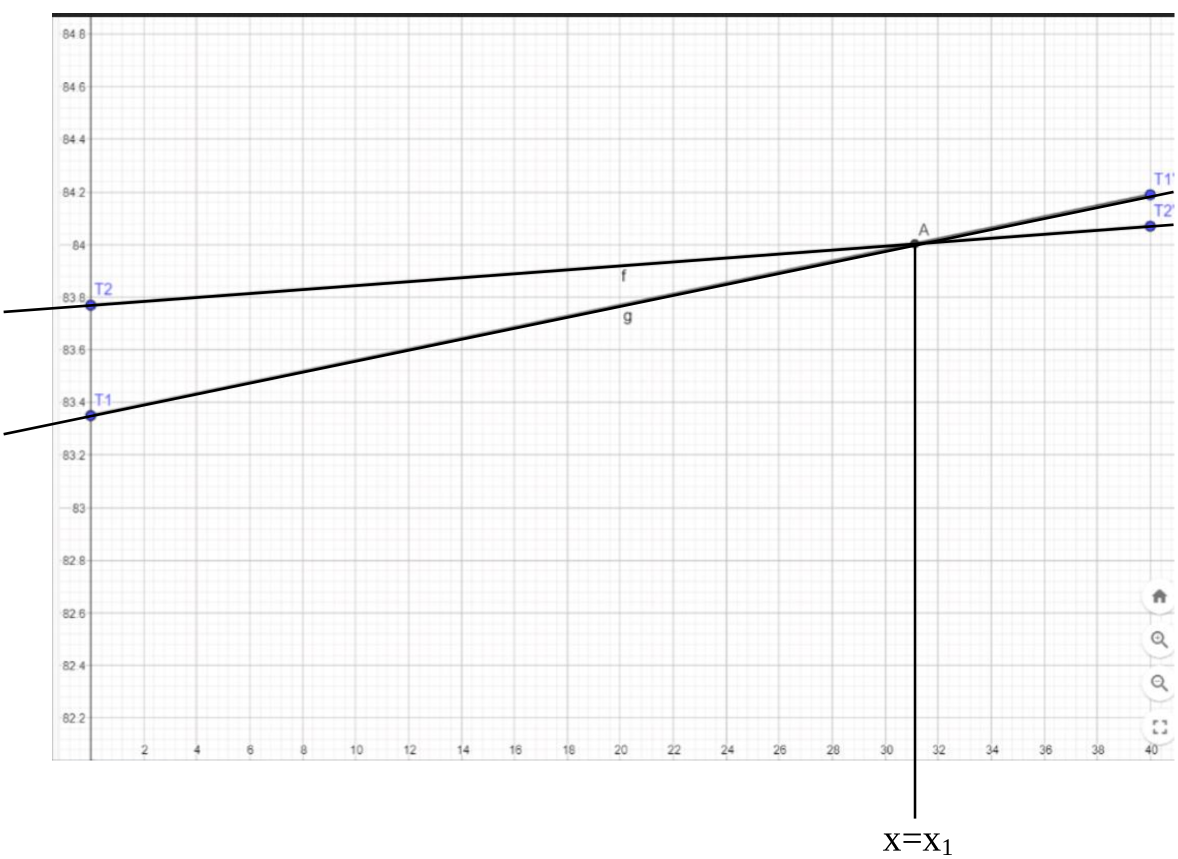

Table 2:

At the best position x_1', the physical pendulum becomes $T_1 = T_2 = T$:

$T1 = 84.047$
$T2 = 84.017$
$\Delta T1 = 0.004$
$\Delta T2 = 0.004$

Best position x'_1 = 31.11 (mm)				
Data	$50T_1$ (s)	Δ ($50T_1$)	$50T_2$ (s)	Δ ($50T_2$)
1	84.04	0.007	84.02	0.003
2	84.05	0.003	84.01	0.007
3	84.05	0.003	84.02	0.003
Avg.	84.047	0.004	84.017	0.004

V. Calculations

1. Determining the oscillating period of the reversible pendulum:

- *Calculate the mean period T of the reversible pendulum from the values in table 2:*
  $\overline{T} = \frac{1}{50}.\frac{(50\overline{T_1}+50\overline{T_2})}{2} = \frac{1}{50}.\frac{(84.047+84.017)}{2} = 1.6806(s)$
- *Random error of T:* $\overline{\Delta T} = \frac{1}{50}.\frac{(50\overline{\Delta T_1}+50\overline{\Delta T_2})}{2} = \frac{1}{50}.\frac{(0.004+0.004)}{2} = 0.8000 \text{ x}10^{-4}(s)$
- *Systematic error of T:* $\Delta T_{sys} = \frac{(0.01)}{50} = 0.0002\ (s)$
- *Absolute error of T:* $\Delta T = \Delta T_{sys} + \Delta T = 0.0002 + 0.004 = 0.0042\ (s)$

2. Calculate the gravitational acceleration:

- *Calculate the mean value of gravitational acceleration:* $\overline{g} = \frac{4\pi^2\overline{L}}{\overline{T}^2} = 9.7843\ (\frac{m}{s^2})$
- Calculate the relative error of g: $\frac{\Delta g}{\overline{g}} = 2\frac{\Delta\pi}{\overline{\pi}} + \frac{\Delta L}{\overline{L}} + 2\frac{\Delta T}{\overline{T}}$
  $=2\frac{0.005}{3.140} + \frac{0.001}{0.700} + 2\frac{0.8000\text{x}10^{-4}}{1.6806} = 0.0047 = \delta$

  $\Rightarrow \Delta g = \delta . \overline{g} = 0.0460\ (\frac{m}{s^2})$

VI. Conclusions:

$g = \overline{g} \pm \Delta g = 9.7843 \pm 0.0460\ (\frac{m}{s^2})$

VII. Question:

1. **What is the same and different between the physical pendulum and mathematical pendulum?**

• The same:

- When considering oscillations with the acceleration of gravity, they all move with the same period formula, and they all make oscillations around a fixed point or axis under the influence of gravity.

• About the difference:

- Mathematical pendulum: consisting of an inextensible string of negligible mass, one end tied to a fixed point and the other end hanging a ball or a point of mass m, the mathematical pendulum mainly studies dynamics particle learning, where the particle is conventionally sized to 0 but still has an arbitrary mass.

- Physical pendulum: is any solid with a definite mass and center of gravity, the axis of rotation lies within itself (does not pass through the center of gravity) and does not represent the object as a point object.

2. **Prove that any physical pendulum hanging given point O_1 can be found O_2 to let the pendulum become irreversible.**

In fact, we have such a point O_2: When the pendulum's oscillation around the axis passes through the point O_2 and the period of oscillation T_2 of the pendulum is determined by the formula:

$$T_2 = \frac{2\pi}{\omega_2} = 2\pi.\sqrt{\frac{I_2}{mg.L_2}}$$

Where $L_2 = O_2G$ is the distance from the axis of rotation passing through the point O_2 to the center of mass G and I_2 is the moment of inertia of the pendulum about the axis of rotation passing through O_2 . Let IG be the moment of inertia of the axis of rotation passing through the center of mass G and parallel to 2 axes passing through O_1 and O_2. According to Huygens-Steiner Theorem:

$$I_1 = I_G + mL_{21}$$

$$I_2 = I_G + mL_{22}$$

If point O_2 satisfies the condition $T_1 = T_2$, then

$$T_1 = \frac{2\pi}{\omega_1} = 2\pi.\sqrt{\frac{I_1}{mg.L_1}}$$

We get the expression to determine the position O_2:

$$L_1.L_2 = \frac{I_G}{m}$$

3. Show the way to adjust Weighted C to becoming a reversible pendulum with two given suspension points O_1, O_2.

Turn weight C to close to weight 4. Use a caliper to measure the x_0 distance between them. Write the value x_0 to the table. Place the pendulum on the support in the forward direction, then measure the time of 50 oscillation cycles and record in the table , under column $50T_1$. Invert the pendulum and measure the time of 50 reverse cycles, recording the results in Table 1 under column $50T_2$. Turn weight C to a position that is a distance from weight 4 $x' = x_0$+40mm. Measure the time 50 forward and 50 reverse cycles for this position, record the results in the table.

Display measurement results on a graph: vertical axis is 120mm long, time representation is $50T_1$ and $50T_2$, horizontal axis is 80mm long, represents x position of weight C. Connect the $50T_1$ points together and the $50T_2$ points together by using line segments, their intersection is the approximate point of position x_1 of weight C to get $T_1 = T_2 = T$. Use a caliper to set weight C to the correct position x_1. Measure $50T_1$ and $50T_2$. Record the results in the table, to the right of the cutoff point, $50T_1 > 50T_2$. From the results of measurement 5 at position x_1 we can draw a comment that we need to move the weight C in which direction to get the best results so that $50T_1 = 50T_2$. Finally, a good position can be determined. maximum of weight C.

We have an important field that defines the expression:

$$g = \frac{4\pi^2.(L_1 + L_2).(L_1 - L_2)}{T_1^2.L_1 - T_2^2.L_2}$$

If $T = T_1 = T_2$, $L = O_1O_2 = L_1 + L_2$ get the formula:

$$g = \frac{4\pi^2.L}{T^2}$$

$$T = 2\pi\frac{l}{g}$$

4. Write expressions identify oscillation period of a reversible pendulum with small amplitude.

We have the expression for the acceleration due to gravity:

$$g = \frac{4\pi^2.(L_1 + L_2).(L_1 - L_2)}{{T_1}^2 L_1 - {T_2}^2 L_2}$$

If $T = T_1 = T_2$, $L = O_1O_2 = L_1 + L_2$, we have the formula:

$$g = \frac{4\pi^2.L}{T^2}$$

And

$$\mathrm{T} = 2\pi\frac{l}{g}$$

5. To determine the oscillation period of a reversible pendulum, we must measure many periods (50 periods for example), but not measure each period? When such a measure, which error that can overcome? How to calculate this kind of error?

To determine the period of oscillation of a reversible pendulum, we must measure many periods because to overcome the random error and in such a measurement we can overcome the error of the measurement and the error of the measuring instrument. The error of the measurement is calculated according to the formula:

$$\Delta T = (\,\Delta T\,)_{dc} + \Delta\overline{T}$$

6. Write a formula to measure the errors by using reversible pendulum? in the formula, determines the number of $\boldsymbol{\pi}$?

The measurement error g with a reversible pendulum is calculated by the formula:

$$\Delta g = \delta.\overline{g} = \left(\frac{\Delta L}{\overline{L}} + \frac{2\Delta T}{\overline{T}} + \frac{2\Delta\pi}{\overline{\pi}}\right).\overline{g}$$

where if $\pi = 3.14$, the error value of the number will be equal to: $\Delta\pi = 0.01$.