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شهادة ادارية

المصادقة على تقارير خبرة للموافقة على مطبوعة بيداغوجية

بعد الإطلاع على تقارير لجنة الخبراء للموافقة على المطبوعة البيداغوجية للأستاذ : **ديلمي إسماعيل – أستاذ محاضر قسم ب**، بالقاعدة المشتركة بكلية التكنولوجيا بجامعة محمد بوضياف بالمسيلة والتي كانت كلها ايجابية ، تمّ تقرير التّالي:

1–المصادقة على تقارير لجنة الخبراء للموافقة المطبوعة البيداغوجية والمعنونة بـ:

Practical Work of Physics 1
Common Base ST– Cycle License

2– حيث تمّ تشكيل هذه اللجنة بناء على اجتماع المجلس العلمي للكلية المنعقد بتاريخ **2025/11/30** المكونة من السّادة الآتية أسماؤهم:

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وتمت الموافقة بالاجماع على هذه المطبوعة.

رئيس المجلس العلمي للكلية

جامعة محمد بوضياف المسيلة – المجلس العلمي – كلية التكنولوجيا

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FACULTY OF TECHNOLOGY
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Practical Work of Physics 1

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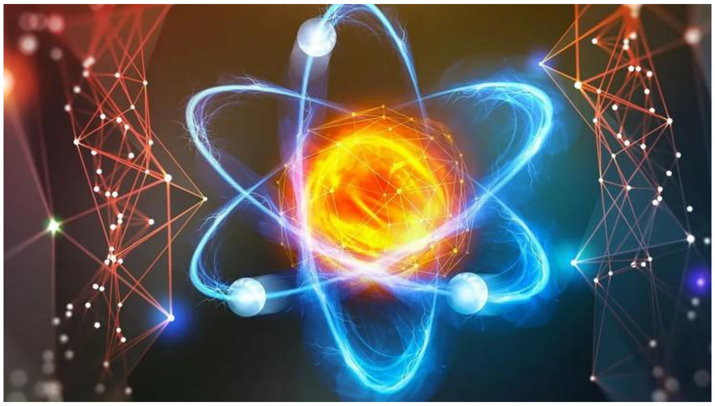

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Academic Year : 2025/2026

Contents

GENERAL INTRODUCTION

Physics is a fundamental science that seeks to explain the laws governing nature, from the motion of planets to the behavior of microscopic particles. A key aspect of physics lies in its experimental foundation, where theories are tested and validated through observation and measurement. Practical work in physics provides students with the opportunity to bridge the gap between theoretical concepts and real-world applications.

Through carefully designed experiments, students learn how to measure physical quantities, analyze uncertainties, and apply mathematical models to describe physical phenomena. These experiments also develop essential scientific skills such as observation, critical thinking, teamwork, and problem-solving.

This module is specifically directed to first-year science and technology students in the common base, aiming to provide them with a solid foundation in experimental physics. It prepares students for advanced studies by developing laboratory techniques, enhancing measurement accuracy, and strengthening the connection between theory and practice.

In this module, students will engage with a variety of classical experiments covering mechanics and measurement. The practical sessions include:

- Measurement techniques and error analysis.
- Verification of Newton's second law of motion.
- Study of free fall under gravity.
- Investigation of the oscillatory motion of a simple pendulum.
- Exploration of elastic and inelastic collisions.
- Analysis of moments of inertia and torsional motion.

By the end of these practical works, students will not only reinforce their understanding of the theoretical principles studied in lectures but also gain hands-on experience in applying the scientific method to physical systems. This foundation is essential for advancing in physics and engineering disciplines.

PRACTICAL WORK N°1: MEASUREMENTS AND ERROR CALCULATION

1. Objectives

By the end of this practical work, the student will be able to:

- Define basic terms such as measurement, precision, and error.
- Explain the difference between systematic and random errors.
- Use appropriate instruments (e.g., ruler, vernier caliper, mass balance) to take measurements of physical quantities.
- Distinguish between absolute, relative, and percentage errors in an experiment.
- Assess the accuracy and precision of measurements and identify sources of error.
- Construct error tables and calculate propagated errors from multiple measurements.

2. Introduction

In physics, accurate and precise measurement of physical quantities is fundamental to understanding the natural world. Since no measurement is perfectly exact, it is essential to understand and quantify errors. This practical introduces the concept of measurement, the proper use of basic instruments, and how to estimate and analyze different types of errors. Developing these foundational skills ensures that future experimental results are reliable and scientifically valid.

3. Basic Concepts

3.1. Physical Quantities and Units

a. **Physical Quantity:** A property that can be measured, such as length, mass, time, etc.
b. **Fundamental Units:** Basic units defined by the International System of Units (SI), like meter (m), kilogram (kg), second (s).
c. **Derived Units:** Combinations of fundamental units (e.g., m/s^2 for acceleration).

3.2. Definition of Error

In physics, an error is the difference between a measured value and the true or accepted value of a quantity. It represents the uncertainty or limitation in the accuracy of a measurement due to imperfections in instruments, methods, or human observation.

$$\delta_e = x_{measured} - x_{real}$$

3.3.Types of errors

a. **Systematic Error:** Consistent, repeatable error due to a flaw in the instrument or method.

b. **Random Error:** Error due to unpredictable fluctuations in the measurement process.

4. Statistical calculation

a. **Average (Mean):** The average is the sum of all measured values divided by the number of measurements. It gives a representative value for repeated readings.

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Where $x_1, x_2, \ldots, x_n$ are the measured values and n is the number of readings.

b. **Absolute uncertainty**

Direct Measurements: When a physical quantity is measured directly (e.g., length with a ruler), absolute uncertainty is the limit within which the true value is expected to lie. It is defined as follows:

$$\Delta x = max|\delta_e|$$

Indirect Measurements: When a quantity is calculated using multiple measured values (e.g., volume from length × width × height), the absolute uncertainty must be propagated using appropriate error rules. The general expression for absolute uncertainty in the case of indirect measurement is given as follows:

$$\Delta f = \left|\frac{\partial f}{\partial x_1}\right| \Delta x_1 + \left|\frac{\partial f}{\partial x_2}\right| \Delta x_2 + \left|\frac{\partial f}{\partial x_3}\right| \Delta x_3 + \cdots$$

c. **Relative Uncertainty (Precision)**

Relative uncertainty expresses the uncertainty as a fraction of the measured value. It shows how precise a measurement is relative to its size.

$$Relative\ uncertainty = \frac{\Delta x}{\bar{x}}$$

To express it as a percentage:

$$Percentage\ uncertainty = \left(\frac{\Delta x}{\bar{x}}\right) \times 100\%$$

d. Operations on Uncertainties

- **Addition and Subtraction**

If a quantity Z is obtained by addition or subtraction:

$$Z = A \pm B$$

The absolute uncertainty of Z is:

$$\Delta Z = \Delta A + \Delta B$$

Remark:

- The same rule applies for subtraction.
- Absolute uncertainties are added directly.

Example:

$$L = (12 \pm 0.1)\ cm, \qquad l = (5 \pm 0.1)\ cm$$

$$S = L - l = 7\ cm, \qquad \Delta S = 0.1 + 0.1 = 0.2\ cm$$

- **Multiplication and Division**

If a quantity Z is obtained by multiplication or division:

$$Z = A \times B \text{ or } Z = \frac{A}{B}$$

The relative uncertainty is:

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

Thus, the absolute uncertainty is:

$$\Delta Z = Z\left(\frac{\Delta A}{A} + \frac{\Delta B}{B}\right)$$

Remark:

- Multiplication and division follow the same rule for uncertainties.

e. The measured value

The measured value is written in the following form:

$$x = \overline{x} \pm \Delta x$$

5. Theoretical preparation

We want to determine the surface of a rectangle (figure 1). We measure its length l and its width w. The surface is given by the function $S = l \times w$.

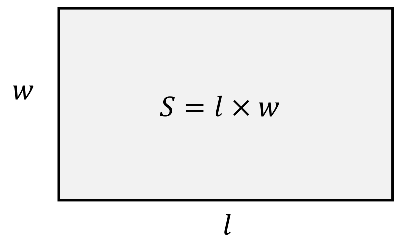

Figure 1.1. The surface of a rectangle of length l and width w.

The values noted are listed in the table 1.1.

Table 1.1.

n° measure	**1**	**2**	**3**	**4**	**5**
$\boldsymbol{w}$ **(cm)**	4. 1	4	4.3	4. 2	4.05
$\boldsymbol{l}$ **(cm)**	6	5.9	6.2	6.1	5.8
$\boldsymbol{S}$ **(cm^2)**	24.6	23.6	26.66	25.62	23.49

Questions :

1) Calculate the average value and absolute uncertainty of w: $\bar{w} = \cdots, \Delta w = \cdots$
2) Calculate the average value and absolute uncertainty of l: $\bar{l} = \cdots, \Delta l = \cdots$
3) Calculate the average of S: $\bar{S} = \cdots$
4) Give the expression of absolute uncertainty ΔS as a function of $w, l, \Delta w$, and Δl.

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5) Calculate the absolute and relative uncertainty: $\Delta S = \cdots, \Delta S/S = \cdots$
6) Write the measured value of the quantity S: $S = \cdots$

6. Manipulation

a. The equipment

- Steel ball (Figure 1.2).
- Mass balance (Figure 1.3).
- Vernier caliper (Figure 1.4).

Figure 1.2. Steel ball.

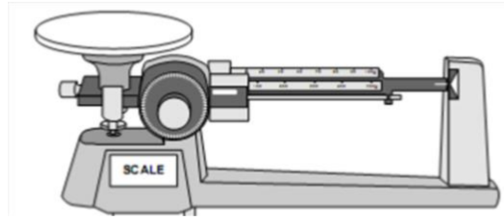

Figure 1.3. Mass balance.

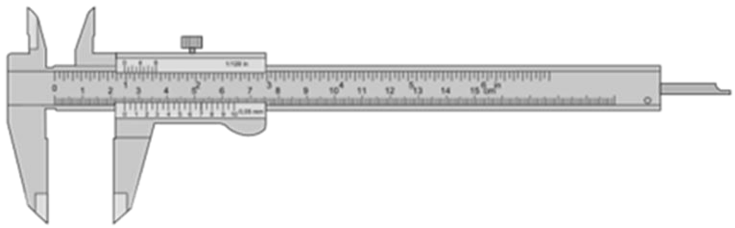

Figure 1.4. Vernier caliper.

b. Measurement of volumetric mass ρ

1- Take a steel ball, measure your mass m, repeat the procedure 5 times, and record the result to the table.

2- Take the same ball, measure its radius R, repeat the procedure 5 times, and record the result on the table.

Table 1.2.

n° measure	**1**	**2**	**3**	**4**	**5**
m**(gr)**					
R**(cm)**					
r**(cm)**					
V**(cm^3)**					
ρ**(gr/cm^3)**					

Questions :

1) Complete the Table 1.2.
2) Calculate the average of m: $\bar{m} = \cdots$
3) Calculate the absolute and relative uncertainty: $\Delta m = \cdots, \Delta m/m = \cdots$

4) Write the measured value of the quantity m: $m = \cdots$
5) Calculate the average of r: $\bar{r} = \cdots$
6) Calculate the absolute and relative uncertainty: $\Delta r = \cdots, \Delta r/r = \cdots$
7) Write the measured value of the quantity r: $r = \cdots$
8) Give the expression for the volume of a sphere: $V = \cdots$
9) Calculate the average of ρ: $\rho = \cdots$
10) Give the expression for the absolute uncertainty $\Delta\rho$ as a function of $m, r, \Delta m$, and Δr:

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11) Calculate the absolute and relative uncertainty: $\Delta\rho = \cdots, \Delta\rho/\rho = \cdots$
12) Write the measured value of the quantity ρ: $\rho = \cdots$

7. Conclusion

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PRACTICAL WORK N° 2: NEWTON'S SECOND LAW OF MOTION

1. Objectives

By the end of this practical work, the student will be able to:

- State Newton's Second Law of Motion and its mathematical form.
- Explain the relationship between force, mass, and acceleration.
- Use measured values of mass and acceleration to verify Newton's Second Law.
- Interpret data to determine how changing mass or force affects acceleration.
- Identify sources of error in the experiment and evaluate result reliability.
- Design graphs and tables to represent the relationship between force and acceleration.

2. Introduction

Newton's Second Law of Motion is fundamental in understanding how objects move when acted upon by forces. It states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. In this practical, we will investigate this relationship using a dynamic cart and a pulley system. By applying different forces and measuring the resulting acceleration, we will verify the mathematical form of the law $\vec{F}_{net} = m\vec{a}$.

3. Basic Concepts

3.1.Newton's Second Law

$$\vec{F}_{net} = m\vec{a}$$

Where F_{net} is the *Force* represents a push or pull that can change the motion of an object, measured in newtons (N), m is the *Mass* represents the amount of matter in an object, measured in kilograms (kg), and a is the *Acceleration* represents the rate of change of velocity, measured in meters per second squared (m/s^2).

- If the net force increases while mass stays constant, acceleration increases.
- If the mass increases while the force stays constant, acceleration decreases.

4. Theoretical Preparation

A cart of mass $m_c = 0.50\,kg$ is placed on a smooth horizontal track and connected via a light inextensible string to a hanging mass $m_h = 0.20\,kg$ (Figure 2.1). The string passes over a frictionless pulley. When the system is released, the hanging mass accelerates downward, pulling the cart horizontally.

Assume $g = 9.8\,m/s^2$.

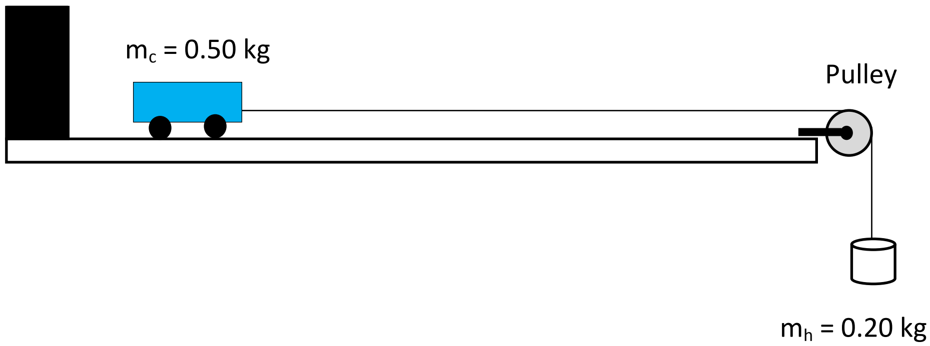

Figure 2.1. Pulley-Cart System for Newton's Second Law of Motion.

Questions:

1) What does Newton's Second Law say about the relationship between force and acceleration?

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2) Write the expression for the net force acting on the system and determine its value.

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3) Calculate the total mass of the system.

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4) Write the expression for the acceleration of the system in terms of m_c, m_h, and g, and determine its theoretical value.

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5) How would the acceleration change if you:
   - Increase the hanging mass m_h?
   - Increase the mass of the cart m_c?

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6) What physical quantity can be measured to compute acceleration? What formula would you use for that?

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7) How would you verify Newton's Second Law experimentally using this setup?

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5. Manipulation

a. The equipment

- Trolley of mass $m_T = 250$g.
- Mass port $m_p = 5$g.
- Set of slotted masses.
- Mass balance.
- Tab of $\delta x = 5mm$.
- Pulley and string.
- Two optical barriers.
- Electronic counter.
- Meter scale or measuring tape.
- Smooth track.
- A Blower.

b. Experiment 1

1- Make the experimental setup in Figure 2.2.

2- Add a mass of 100g to the mass of the trolley.

3- Add a hanging mass $m_h = 55$g to the mass port $m_p = 5$g so that $m_2 = 60$g.

4- Place the tab on the trolley.

5- Place the first optical barrier at the initial position such that $d = 0$.

6- Turn on the blower.

7- Release the trolley and record the time t it takes to travel the distance d using the electronic counter.

8- Choose a new distance by adding 0.1 m to the previous distance, then repeat steps 6 and 7. To change the distance d, keep optical barrier 1 fixed and move only optical barrier 2.

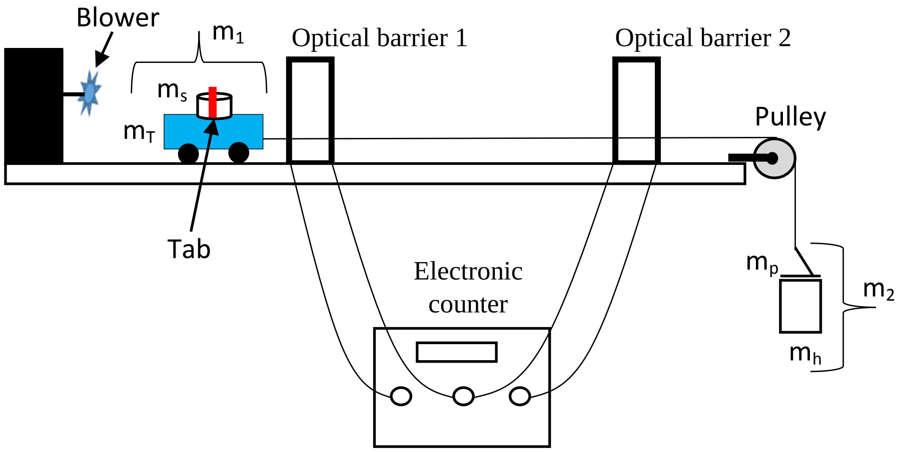


Figure 2.2. The experimental setup to verify Newton's second law.

Table 2.1

d(m)		0.3	0.4	0.5	0.6	0.7
t(s)	Trial 1					
	Trial 2					
	Trial 3					
t_{mean}(s)						
Δt(s)						
t_{mean}^2(s^2)						
Δt^2(s^2)						
g_{exp}(m/s^2)						
Δg(m/s^2)						

Notes:

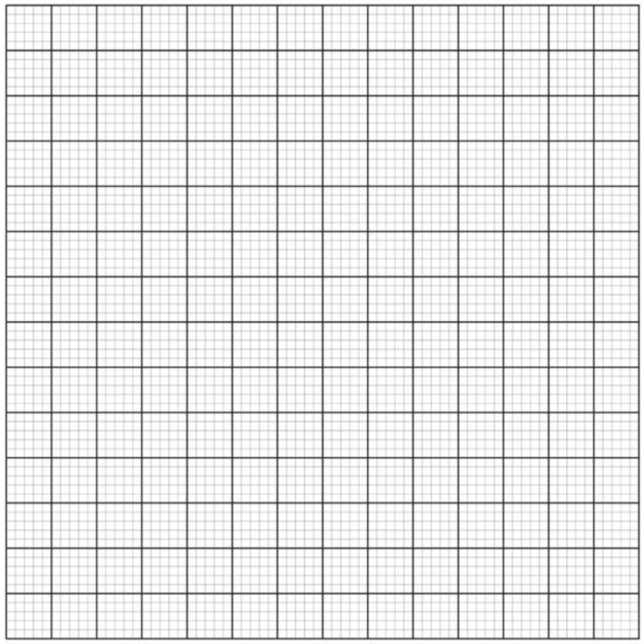
- To calculate the experimental gravitational acceleration g_{exp}, we use the formula: $g_{exp} = a_{exp}\frac{m_1+m_2}{m_2}$.
- To calculate the experimental acceleration a_{exp}, we use the formula: $a_{exp} = \frac{2d}{t^2}$.

Questions:

1) Complete the Table 2.1.
2) Plot the graph $d = f(t_{mean}^2)$ (Figure below).

Title: ……………………………………………………

Label (Y-axis): ……………………………………………………



Label (X-axis): ……………………………………………………

3) Deduce the gravitational acceleration g_{graph} and compare it with g_{exp}.

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4) Write the gravitational acceleration g_{exp} in the form $g_{exp} = \bar{g} \pm \Delta g$.

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5) What distance, short or long, do you use to get the best g value?

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c. Experiment 2

To study the relationship between the acceleration (a) of the system and the force (F), we maintain the system shown in Figure 2.2, with a change in the mass m_2, while keeping the total mass of the system $(m_1 + m_2)$ constant.

1- Vary the mass m_2 (e.g., 20 g, 40 g, 60 g, 80 g, 100 g), which acts as the applied force $F = m_2.g$, so that the total mass of the system $(m_1 + m_2)$ remains constant. We take the value of $\bar{g}$ obtained from Experiment 1.
2- For each value of m_2, allow the trolley to accelerate and use the electronic counter to measure the time t it takes to travel a fixed distance d.

Table 2.2

m_2(kg)	0.02	0.04	0.06	0.08	0.1
t(s)					
$t^2(s^2)$					
F(N)					
a_{exp}(m/s^2)					

Note: To calculate the acceleration a_{exp}, we use the formula: $a_{exp} = 2d/t^2$.

Questions:

1) Complete the Table 2.2.
2) Plot the graph of Force vs. Acceleration (Figure below) with:
   - X-axis: Acceleration
   - Y-axis: Applied force
3) Verify Newton's second law?

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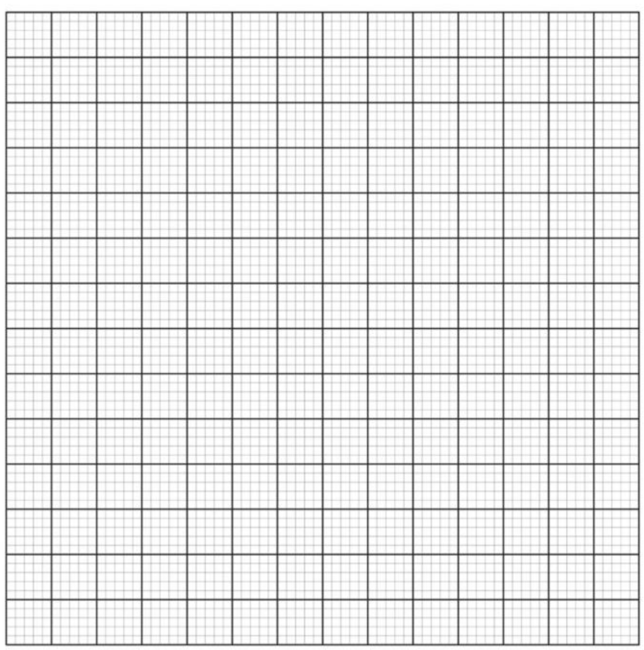
Title: ………………………………………………

Label (Y-axis): ………………………………………



Label (X-axis): ………………………………………………

6. Conclusion

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PRACTICAL WORK N° 3: FREE FALL

1. Objectives

By the end of this practical work, the student will be able to:

- Experimentally verify that the motion of a freely falling body is uniformly accelerated.
- Plot $h = f(t^2)$ and deduce the value of g.
- Interpret experimental data using graphs and equations of uniformly accelerated motion.

2. Introduction

Free fall is the motion of an object under the influence of gravity alone, without any resistance from air or other forces. When an object is released from rest and falls vertically near the Earth's surface, it accelerates uniformly due to the gravitational field. This acceleration is denoted by g, and its standard value is approximately 9.8 m/s^2.

In this experiment, we will study the motion of a freely falling object by measuring the time it takes for the object to fall from various known heights, we can verify that the motion is uniformly accelerated and determine the value of the gravitational acceleration g.

3. Basic Concepts

- A body in free fall is under the action of gravity alone.
- The acceleration due to gravity g near the Earth's surface is approximately 9.8 m/s^2.
- For an object falling from rest:

$$h = \frac{1}{2} g t^2$$

where h(m) is the vertical displacement, t(s) is the time of fall, and g(m/s^2) is the acceleration due to gravity.

During free fall, a body possesses two important forms of mechanical energy:

a. Potential Energy (E_p)

Potential energy is the energy stored by an object due to its position in a gravitational field.

$$E_p = m.g.h$$

where E_p(J) is the gravitational potential energy and m(kg) is the mass of the object.

b. Kinetic Energy (E_c)

Kinetic energy is the energy an object has due to its motion.

$$E_c = \frac{1}{2}mv^2$$

where E_c(J) is the kinetic energy, m(kg) is the mass of the object, and v(m/s) is the velocity of the object just before hitting the ground or sensor.

- At the start of free fall (when the object is held at height h), it has maximum potential energy and zero kinetic energy.
- As the object falls, potential energy is converted into kinetic energy.
- At the end of the fall (just before impact), potential energy becomes zero, and the object reaches its maximum kinetic energy.

In the absence of air resistance, the total mechanical energy is conserved:

$$E_p^{Initial} = E_c^{Final} \Rightarrow m.g.h = \frac{1}{2}mv^2$$

We can cancel the mass m from both sides:

$$g.h = \frac{1}{2}v^2 \Rightarrow v = \sqrt{2gh}$$

4. Theoretical Preparation

A small steel ball of mass $m = 17$ g is released from rest and allowed to fall freely from a height $h = 1.20$ m (Figure 3.1).

Questions:

1) What are the neglected forces in free fall?

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2) Calculate the time t it takes for the ball to reach the ground (Take $g = 9.8\,m/s^2$).

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3) Calculate the velocity of the ball just before it hits the ground.

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4) Calculate the potential energy of the ball at the start.

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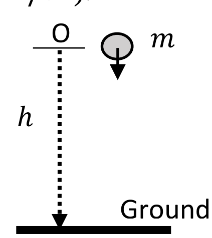

Figure 3.1. Free fall.

5) Calculate the kinetic energy of the ball just before impact.

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6) Verify that mechanical energy is conserved.

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7) What is the nature of the motion of free fall?

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5. Manipulation

a. The equipment

- Steel ball with a mass of 17 g.
- Rigid vertical support with adjustable height.
- Meter rule.
- Trigger.
- Two optical barriers.
- Electronic counter.

b. Experiment 1

1- Make the experimental setup in Figure 3.2.

2- Adjust the height h using a meter rule.

3- Press the trigger to start the fall.

4- Record the time t of the fall when the ball reaches the receiving plate using the electronic counter.

5- Change the height h and repeat steps 2-4 for different values.

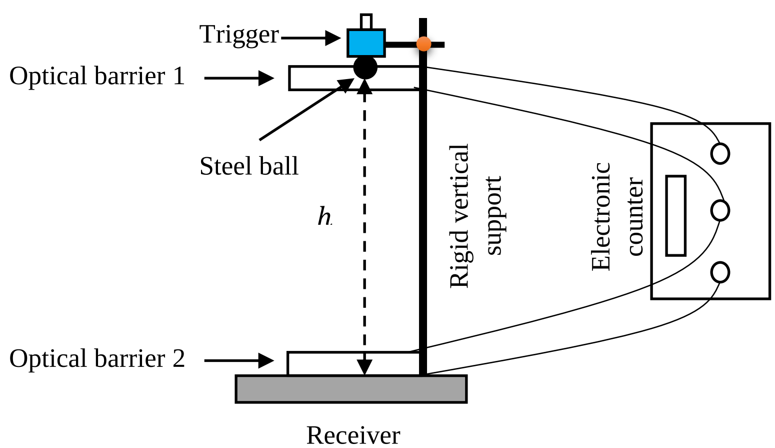


Figure 3.2. The experimental setup.

Table 3.1

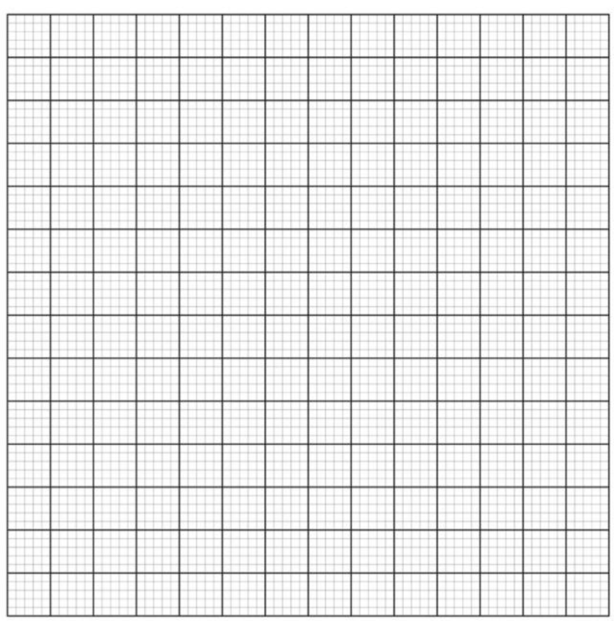
$h(m)$	1	0.8	0.6	0.4	0.2
$t(s)$					
$\Delta t(\mathrm{s})$					
$t^2(\mathrm{s}^2)$					
$\Delta t^2(\mathrm{s}^2)$					
$g_{exp}(\mathrm{m/s^2})$					
$\Delta g(\mathrm{m/s^2})$					
$v(\mathrm{m/s})$					
$E_p(\mathrm{J})$					
$E_c(\mathrm{J})$					
E_c/E_p					

Questions:

1) Complete the Table 3.1.
2) Plot the graph $h = f(t^2)$ (Figure below).

Title: ……………………………………………………

Label (Y-axis): ……………………………………………………



Label (X-axis): ……………………………………………………

3) Deduce the acceleration from the graph (g_{graph}) and compare it with g_{exp}.

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4) Write the acceleration g_{exp} in the form $g_{exp} = \bar{g} \pm \Delta g$.

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5) Is mechanical energy conserved? Justify.

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6. Conclusion

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PRACTICAL WORK N° 4: SIMPLE PENDULUM

1. Objectives

By the end of this practical work, the student will be able to:

- Describe the periodic motion of a simple pendulum.
- Measure the period of oscillation for various lengths.
- Plot the graph $T^2 = f(L)$ and deduce the value of g.
- Analyze sources of error and experimental limitations.

2. Introduction

The simple pendulum is a classic example of periodic motion in physics. It consists of a small mass, called the bob, suspended from a fixed point by a lightweight and inextensible string. When displaced from its equilibrium position and released, the pendulum swings back and forth under the influence of gravity.

For small angular displacements, the motion of a simple pendulum approximates simple harmonic motion, and its period depends only on the length of the pendulum and the acceleration due to gravity. The simplicity of the system makes it ideal for investigating fundamental concepts such as periodic motion and for experimentally determining the value of gravitational acceleration g.

3. Basic Concepts

A simple pendulum consists of a small mass (called the bob) suspended from a fixed point by a light, inextensible string. When displaced slightly and released, it oscillates back and forth under the influence of gravity (Figure 4.1).

- The pendulum exhibits periodic motion.
- The time for one full oscillation is called the period T.

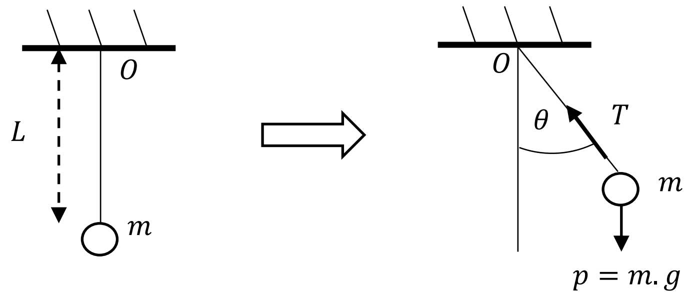

Figure 4.1. Simple pendulum system.

For small angular displacements θ, the motion is approximately simple harmonic and the period is given by:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Where T is the period of the pendulum, L is the length of the pendulum, and g is the acceleration due to gravity.

4. Theoretical Preparation

A student sets up a simple pendulum with a string length of $L = 0.60$ m. The pendulum bob is displaced by a small angle (less than 15°) and released from rest.

Questions:

1) Write the formula that gives the period T of a simple pendulum in terms of L and g.
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2) Using $g = 9.8$ m/s², calculate the theoretical period T of the pendulum.
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3) Determine the square of the period T^2.
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4) If the measured time for 10 oscillations is $t = 15.5$ s, calculate the experimental period T_{exp}.
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5) Compare the theoretical and experimental values of the period. Is the error acceptable? Explain briefly.
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5. Manipulation

a. The equipment

- Rigid vertical support.
- Light, inextensible string.
- Small metallic bob.
- Stopwatch.
- Meter rule.

b. Experiment 1

1- Make the experimental setup in Figure 4.2.

2- Fix the string of length L to a stand so the pendulum can swing freely.

3- Displace the bob by a small angle ($\theta \leq 15^{\circ}$) and release it without pushing.

4- Measure the time t for 10 complete oscillations using a stopwatch.

5- Calculate the period T using: $T = \frac{t}{10}$.

6- Repeat the measurement three times for accuracy and calculate the average period.

7- Change the length L of the pendulum and repeat steps 2–5 for different values (e.g., 30 cm, 40 cm, 50 cm, 60 cm, 70 cm).

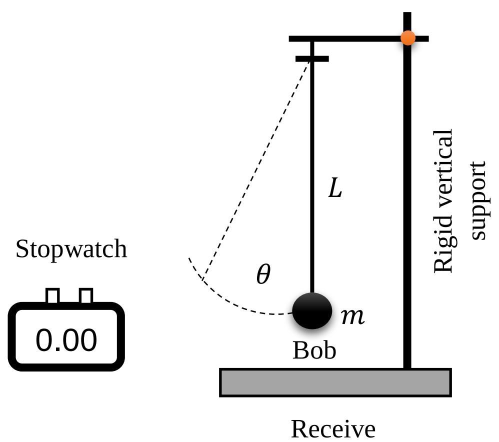


Figure 4.2. The experimental setup of the simple pendulum system.

Table 4.1

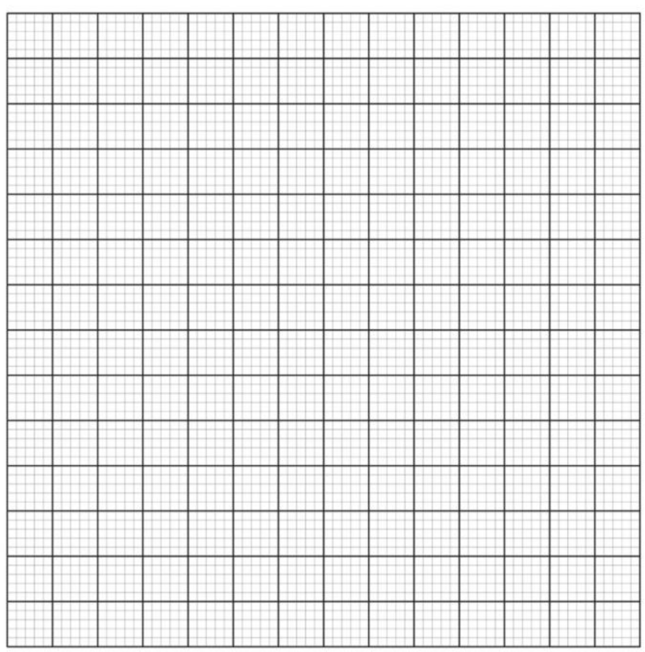
$L(\text{m})$		0.3	0.4	0.5	0.6	0.7
$t(\text{s})$	Trial 1					
	Trial 2					
	Trial 3					
$t_{mean}(\text{s})$						
$T(s)$						
$T^2(s)$						
$g_{exp}(\text{m/s}^2)$						
$\Delta g(\text{m/s}^2)$						

Questions:

1) Complete the Table 4.1.
2) Plot the graph $T^2 = f(L)$ (Figure below).

Title: ....

Label (Y-axis): ....



Label (X-axis): ....

3) Deduce the acceleration from the graph (g_{graph}) and compare it with g_{exp}.

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4) Write the acceleration g_{exp} in the form $g_{exp} = \bar{g} \pm \Delta g$.

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6. Conclusion

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PRACTICAL WORK N° 5: ELASTIC AND INELASTIC COLLISION

1. Objectives

By the end of this practical work, the student will be able to:

- Distinguish between elastic and inelastic collisions based on conservation laws.
- Apply the principles of conservation of momentum and kinetic energy.
- Analyze the experimental results and classify the type of collision.

2. Introduction

Collisions are common phenomena in physics where two or more bodies interact over a short time interval, exchanging momentum and energy. Understanding collisions is essential for analyzing motion in mechanics, from simple carts on a track to complex systems like vehicle crashes or particle interactions.

In this practical work, we focus on one-dimensional collisions between two carts. There are two primary types of collisions:

- Elastic collisions, where both momentum and kinetic energy are conserved.
- Inelastic collisions, where momentum is conserved, but kinetic energy is partially lost, usually transformed into heat, sound, or deformation. In a perfectly inelastic collision, the bodies stick together after the impact.

3. Basic Concepts

The momentum (P) of a material point of mass m and speed v is defined by:

$$\vec{P} = m\vec{v}$$

The kinetic energy (E_k) of a material point of mass m and speed v is defined by:

$$E_k = \frac{1}{2}mv^2$$

A collision occurs when two objects exert forces on each other over a short time interval. Collisions are classified as:

a. Elastic Collision

The total momentum and kinetic energy are conserved.

$$\begin{cases} P_1 + P_2 = P_1' + P_2' \\ E_{k1} + E_{k2} = E_{k1}' + E_{k2}' \end{cases}$$

Where:

$P_1 = m_1 v_1$, is the momentum of the body of mass m_1 before the collision.

$P_2 = m_2 v_2$, is the momentum of the body of mass m_2 before the collision.

$E_{k1} = \frac{1}{2} m_1 v_1$, is the kinetic energy of the body of mass m_1 before the collision.

$E_{k2} = \frac{1}{2} m_2 v_2$, is the kinetic energy of the body of mass m_2 before the collision.

$P_1' = m_1 v_1'$, is the momentum of the body of mass m_1 after the collision.

$P_2' = m_2 v_2'$, is the momentum of the body of mass m_2 after the collision.

$E_{k1}' = \frac{1}{2} m_1 v_1'^2$, is the kinetic energy of the body of mass m_1 after the collision.

$E_{k2}' = \frac{1}{2} m_2 v_2'^2$, is the kinetic energy of the body of mass m_2 after the collision.

b. Inelastic Collision

The total momentum is conserved, but the total kinetic energy is not conserved (some is lost to sound, heat, deformation).

$$\begin{cases} P_1 + P_2 = P_1' + P_2' \\ E_{k1} + E_{k2} > E_{k1}' + E_{k2}' \end{cases}$$

4. Theoretical Preparation

Two carts on a frictionless air track collide. Cart 1 has a mass of $m_1 = 0.5$ kg and moves at $v_1^{Initial} = 0.8$ m/s. Cart 2 is at rest with a mass of $m_2 = 0.5$ kg.

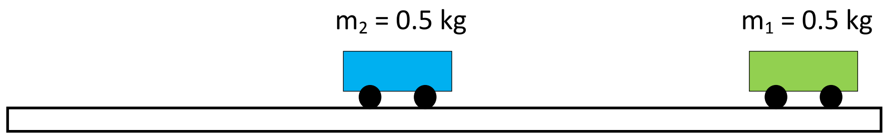

Figure 5.1. Collision between to carts.

Questions:

1) Write the expression for total momentum before and after the collision.

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2) Assume the collision is perfectly elastic, and that the carts exchange velocities. What are the final velocities v_1' and v_2' after the collision?

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3) Calculate the total kinetic energy before and after the collision.

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4) Now assume the collision is perfectly inelastic (carts stick together). What is their common final velocity v^{Final}?

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5) Calculate the total kinetic energy after the inelastic collision and compare it with the initial energy. Is energy conserved?

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6) What physical quantity is always conserved in both elastic and inelastic collisions?

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5. Manipulation

a. The equipment

- Two carts of masses $m_{c1} = m_{c2} = 250$g.
- Set of slotted masses.
- Smooth track.
- Mass balance.
- Two optical barriers.
- Electronic counter.
- Two tabs of $\delta x = 5$ mm and $m_t = 5$g.

b. Experiment 1: Elastic Collision

1- Carry out the assembly as shown in Figure 5.2.

2- Before the collision, the first cart has a variable mass $m_1 = 0.265 + m_{overload}$ kg and is in motion. While the second cart is in a rest state with a fixed mass $m_2 = 0.765$ kg.

3- During the passage of the first cart over the first optical barrier, the electronic counter records the corresponding time Δt_1.

4- After the collision, the two cars move in opposite directions, and each passes through an optical barrier, the electronic counter records time twice $\Delta t'_1$ and $\Delta t'_2$.

5- Repeat the previous steps by varying the mass m_1.

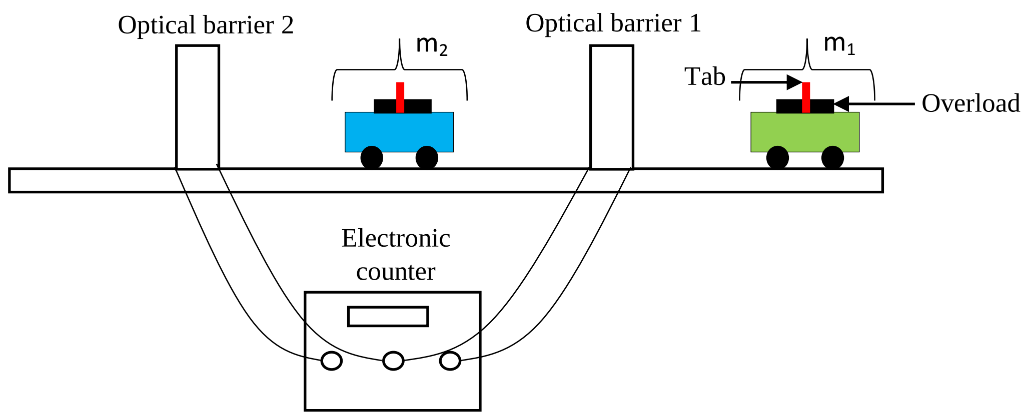

Figure 5.2. The experimental setup.

Table 5.1.

m_1 (kg)	0.265	0.515	0.765	1.015	1.265
Δt_1 (s)					
$\Delta t'_1$ (s)					
$\Delta t'_2$ (s)					
v_1 (m/s)					
v'_1 (m/s)					
v'_2 (m/s)					
P_1 (kg.m/s)					
P'_1 (kg.m/s)					
P'_2 (kg.m/s)					
E_{k1} (J)					
E'_{k1} (J)					
E'_{k2} (J)					
$\frac{(P_1+P_2)}{(P'_1+P'_2)}$					
$\frac{(E_{k1}+E_{k2})}{(E'_{k1}+E'_{k2})}$					

Questions:

1) Complete the Table 5.1.
2) Is there a conservation in the momentum and kinetic energy?

…………………………………………………………………………….………………………

c. Experiment 2: Inelastic Collision

1- Carry out the same assembly illustrated in the previous Figure.

2- Before the collision, the first cart has a variable mass $m_1 = 0.265 + m_{overload}$ kg and is in motion. While the second cart is in a rest state with a fixed mass $m_2 = 0.765$ kg.
3- During the passage of the first car over the first optical barrier, the electronic counter records the corresponding time Δt_1.
4- After the collision, the two cars stick together, move in the same direction with the same speed, and pass through an optical barrier, the electronic counter records the corresponding time $\Delta t'_2$.
5- Repeat the previous steps by varying the mass m_1.

Table 5.2.

m_1 (kg)	0.265	0.515	0.765	1.015	1.265
Δt_1 (s)					
$\Delta t'_2$ (s)					
v_1 (m/s)					
$v'_1 = v'_2$ (m/s)					
P_1 (kg.m/s)					
P'_1 (kg.m/s)					
P'_2 (kg.m/s)					
E_{k1} (J)					
E'_{k1} (J)					
E'_{k2} (J)					
$\frac{(P_1+P_2)}{(P'_1+P'_2)}$					
$\frac{(E_{k1}+E_{k2})}{(E'_{k1}+E'_{k2})}$					

Questions:

1) Complete the Table 5.2.
2) Is there a conservation in the momentum and kinetic energy?

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6. Conclusion

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PRACTICAL WORK N° 6: MOMENTS OF INERTIA AND TORSIONAL MOTIONS

1. Objectives

By the end of this practical work, the student will be able to:

- Understand and define moment of inertia and torsional motion.
- Determine the torsion constant k experimentally.
- Measure the moment of inertia of a rigid body using a torsional pendulum.
- Compare theoretical and experimental values of moment of inertia.

2. Introduction

In rotational motion, just as mass quantifies inertia in linear motion, the moment of inertia quantifies a body's resistance to angular acceleration about an axis. Understanding this concept is essential in analyzing the dynamics of rotating systems such as pendulums, wheels, and machinery.

This practical work aims to explore torsional motion by analyzing the behavior of a rod connected by a torsion wire. When the system is twisted and released, it undergoes angular oscillations governed by a restoring torque that is proportional to the angular displacement.

The practical session is divided into two experiments:

- In the experiment 1, we determine the torsion constant k, which characterizes the restoring torque.
- In the experiment 2, we use the known torsion constant to determine the moment of inertia.

3. Basic Concepts

a. Torsion and Restoring Torque

When a force F is applied at a perpendicular distance r from the axis of a wire, it generates a torque $\mathcal{T}$:

$$\mathcal{T} = r.F = r.m.g$$

This torque twists the wire, and the wire exerts a restoring torque:

$$\mathcal{T} = k.\theta$$

Where θ is the angular displacement in radians and k is the torsional constant (in N·m/rad).

Hence:

$$\mathcal{T} = \frac{r.m.g}{\theta}$$

b. Moment of Inertia and Torsional Oscillation

A torsional pendulum undergoes angular harmonic motion:

$$I.\frac{d^2\theta}{dt^2} = -k.\theta$$

The period of oscillation T is:

$$T = 2\pi\sqrt{\frac{I}{k}} \;\Rightarrow\; I = \frac{kT^2}{4\pi^2}$$

4. Theoretical Preparation

a. Exercise 1: Determining the Torsion Constant

A light rigid rod is fixed horizontally to the end of a torsion wire. Two equal masses, each of mass $m = 200$ g, are attached at equal distances $r = 0.15$ m from the axis of rotation. When the system is released, the rod comes to equilibrium at an angular displacement of 25°.

Questions:

1) Convert the angular displacement θ into radians.

…………………………………………………………………………………………………

2) Compute the downward force F exerted by each mass.

…………………………………………………………………………………………………

3) Calculate the torque contribution of one mass $\mathcal{T}_1$.

…………………………………………………………………………………………………

4) Determine the total torque of the system $\mathcal{T}_{total}$.

…………………………………………………………………………………………………

5) Find the torsion constant k of the wire.

…………………………………………………………………………………………………

b. Exercise 2: Measuring the Moment of Inertia

A uniform rod of mass M and length L is mounted on a torsion pendulum with its axis passing through the centre. Two small equal masses m are fixed symmetrically on the rod at distances r from the axis.

The total moment of inertia is given as:

$$I_{total} = \frac{1}{12}ML^2 + 2mr^2$$

Questions:

1) Explain why the term $\frac{1}{12}ML^2$ corresponds to the rod alone. What physical property of the rod determines its contribution to the inertia?

   ……………………………………………………………………………………………………

2) Why does each added mass contribute mr^2 to the total moment of inertia?

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3) If the masses are moved closer to the axis (smaller r), what happens to the period of oscillation T? Justify using the formula: $T = 2\pi\sqrt{\frac{I}{k}}$.

   ……………………………………………………………………………………………………

4) If the rod were extremely light compared to the two masses, what simplified expression would you obtain for I_{total}?

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5) In practice, how could you experimentally distinguish the rod's own inertia from that of the two masses using the graph I vs. r^2?

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5. Manipulation

a. The equipment

- Axis of rotation.
- A rod of 0.6 m.
- Mass balance.
- Two equal masses.
- Dynamometer.
- Optical barrier.

- Electronic counter.
- Meter rule.

b. Experiment 1: Determination of the Torsion Constant

1- Make the experimental setup in Figure 6.1.
2- Attach the rod to the torsion axis of the pendulum.
3- Using a dynamometer hooked perpendicularly to the rod at distances r from its center, determine the forces F needed to rotate the rod by an angle $\theta = 180°$ from its equilibrium position.
4- Repeat the previous step by varying the distance r.

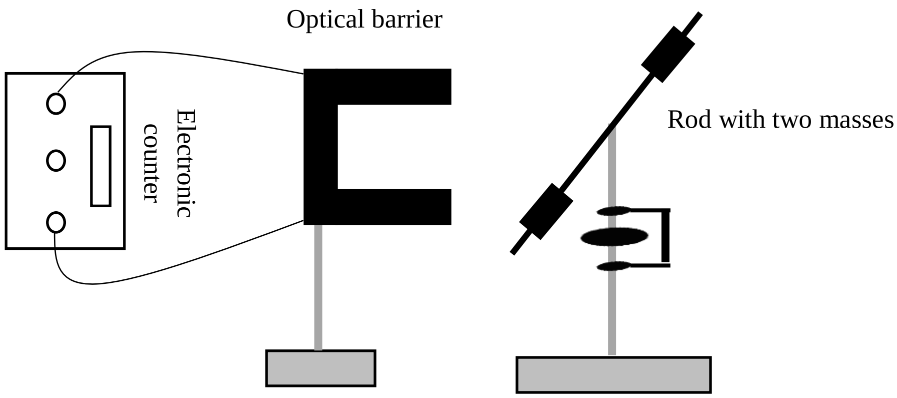


Figure 6.1. The experimental setup.

Table 6.1.

$r\ (m)$	0.17	0.19	0.21	0.23	0.25	0.27	0.29
F (N)							
$\mathcal{T}$ (N.m)							
k (N.m/rad)							
Δk (N.m/rad)							

Questions:

1) Complete the Table 6.1.

………………………………………………………………………………………………………

2) Write the torsion constant k in the form $k = \bar{k} \pm \Delta k$.

…………………………………………………………………………………….………………………

c. Experiment 2: Determination of the Moment of Inertia

1- Slide two identical masses onto the rod, placing them on opposite sides relative to the torsion axis of the pendulum.

2- Using a stopwatch, determine the half-period of oscillation of the rod for each position of the two masses, and then calculate the full period.

3- Repeat the previous step by varying the distance r.

Table 6.2.

$r\ (m)$	0.04	0.08	0.12	0.16	0.2
$T/2$ (s)					
T (s)					
r^2 (m^2)					
$I_{th} = \frac{1}{12}ML^2 + 2mr^2$					
$I_{exp} = \frac{kT^2}{4\pi^2}$					

Note: To calculate the experimental moment of inertia I_{exp}, we use the value $\bar{k}$ obtained from Experiment 1.

Questions:

1) Complete the Table 6.2.

2) Compare between the values of I_{th} and I_{exp}.

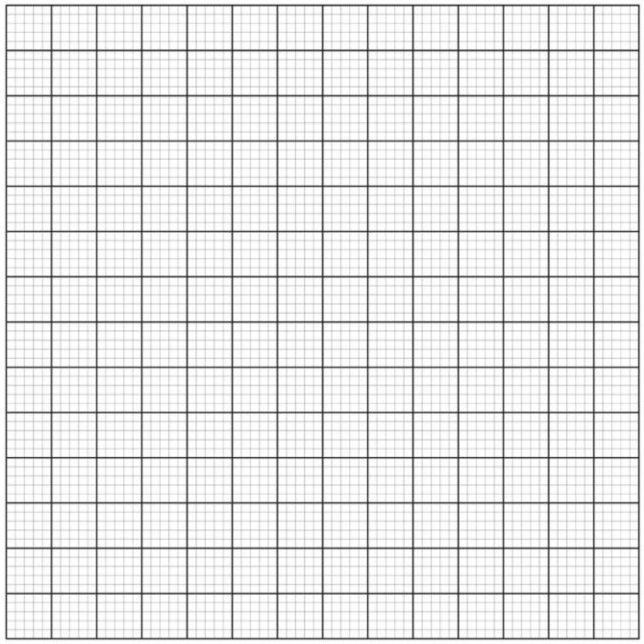
…………………………………………………………………………………….………………………

3) Plot the graph $I_{exp} = f(r^2)$ (Figure below) with:

- X-axis: moment of inertia.
- Y-axis: square of the distance.

Title: ……………………………………………………

Label (Y-axis): ……………………………………………………



Label (X-axis): ……………………………………………………

4) Deduce the moment of inertia of the rod alone I_{rod}.

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6. Conclusion

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