Experiment No. - ……

Aim/Objectives: -

To determine the acceleration due to gravity (g) using a bar pendulum (compound pendulum).

Practical Significance of the Experiment: -

Measuring the acceleration due to gravity (g) is one of the fundamental experiments in Engineering Physics because it helps students understand how gravity influences the motion of objects. Although the experiment is performed in a laboratory, the concept of g is widely used in many real-world engineering and scientific applications.

Accurate knowledge of gravitational acceleration is important in geophysics for studying the Earth's structure and locating natural resources, aerospace engineering for designing satellite and rocket trajectories, and civil engineering for analyzing loads and ensuring the stability of buildings and bridges.

The principles learned from this experiment, such as oscillatory motion, moment of inertia, and center of gravity, are also applied in designing precision clocks, reducing vibrations in industrial machines, improving vehicle suspension systems, and enhancing the stability of ships and aircraft. Overall, this experiment builds a strong foundation for understanding many advanced engineering applications.

Relevant Program Outcomes (POs): -

PO	Program Outcome	Relation to the Experiment
PO1	Engineering Knowledge	Applies fundamental principles of Engineering Physics, mechanics, oscillations, rotational motion, and gravity to determine the acceleration due to gravity experimentally.
PO2	Problem Analysis	Analyzes experimental observations, identifies conjugate points, interprets data, and calculates the value of acceleration due to gravity using appropriate formulas.
PO5	Modern Tool Usage	Uses laboratory instruments such as the bar pendulum, knife-edge support, stopwatch, and meter scale accurately for data collection and analysis.

PO9	Individual and Team Work	Develops the ability to perform experiments individually or collaboratively while maintaining coordination and responsibility in the laboratory.
PO10	Communication	Enhances the ability to prepare clear laboratory records, present observations, explain experimental results, and answer viva questions effectively.
PO12	Life-long Learning	Encourages scientific curiosity, experimental thinking, and continuous learning by connecting theoretical concepts with practical engineering applications.

Relevant Course Outcomes (COs): -

Upon the successful completion of the course module corresponding to this laboratory session, the students will be able to apply the fundamental laws of mechanics and oscillatory motion to physical bodies.

Practical Learning Outcomes: -

After successfully completing the **Bar Pendulum Experiment**, students will be able to:

1. **Understand the working principle of a bar (compound) pendulum** and its oscillatory motion.
2. **Determine the acceleration due to gravity (g)** experimentally using the bar pendulum method.
3. **Measure the time period of oscillations** accurately for different pivot positions using a stopwatch.
4. **Identify the centre of gravity and conjugate points** of the bar pendulum and understand their significance.

Practical Skills Developed: -

1. **Experimental Measurement Skills:** Learn to accurately measure the time period of oscillations and distances using laboratory instruments such as a stopwatch and meter scale.
2. **Observation and Data Recording:** Develop the ability to record experimental readings carefully, organize data systematically, and minimize observational errors.

3. **Analytical and Calculation Skills:** Apply mathematical formulas to calculate the acceleration due to gravity (**g**) and analyze the accuracy of experimental results.
4. **Graphical Interpretation Skills:** Improve the ability to plot and interpret graphs (where applicable) to determine experimental parameters and validate results.
5. **Laboratory Instrument Handling:** Develop confidence in handling laboratory equipment correctly and following standard experimental procedures.
6. **Scientific Reporting Skills:** Enhance the ability to prepare well-structured laboratory records, including observations, calculations, graphs, and conclusions.
7. **Teamwork and Communication Skills:** Strengthen collaboration, discussion, and effective communication while performing experiments and presenting results during practical sessions.

Relevant Affective Domain Outcomes: -

- **Receiving: -** Demonstrate attentiveness to laboratory instructions, safety precautions, and the correct experimental procedure.
- **Responding: -** Actively participate in performing the experiment, recording observations, and discussing the experimental results.
- **Valuing: -** Appreciate the importance of accurate measurements, ethical data recording, and careful handling of laboratory equipment while determining the acceleration due to gravity.
- **Organization (Partially Developed): -** Develop a positive attitude toward maintaining discipline, teamwork, and systematic laboratory practices during experimental work.

Theoretical Background: -

A **bar pendulum**, also known as a **compound pendulum**, is a rigid, uniform metal bar with several holes drilled at equal intervals along its length. It is suspended from one of these holes on a horizontal knife edge and allowed to oscillate freely in a vertical plane under the action of gravity.

Unlike a simple pendulum, the mass of a bar pendulum is distributed throughout the entire bar. Therefore, its motion depends on both the **gravitational force** and the

moment of inertia of the bar. When the bar is displaced through a small angle and released, it performs **Simple Harmonic Motion (SHM)** because the restoring torque is proportional to the angular displacement.

By measuring the time period of oscillation for different pivot positions, the acceleration due to gravity (**g**) can be determined accurately while also understanding the concepts of rotational motion, centre of gravity, and moment of inertia.

The time period of oscillation is given by

$$T = 2\pi \sqrt{\frac{I}{mgl}}$$

where *I* is the moment of inertia of the bar about the axis of suspension, *m* is its mass, *g* is the acceleration due to gravity, and *l* is the distance from the axis of suspension to the centre of gravity.

Using the parallel axis theorem, $I = I_G + ml^2$, where $I_G = mK^2$ is the moment of inertia about the CG and *K* is the **radius of gyration**. Substituting this in gives the more useful working form:

$$T = 2\pi \sqrt{\frac{K^2 + l^2}{gl}}$$

Comparing the compound pendulum formula with the simple pendulum formula T = 2π√(L/g), we can define:

$$L = \frac{K^2 + l^2}{l} = l + \frac{K^2}{l}$$

This *L* is called the **length of the equivalent simple pendulum** — a simple pendulum of this length would oscillate with exactly the same time period as the bar. Rearranging the formula gives the equation to determine the acceleration due to gravity:

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

Experimental Set-up: -

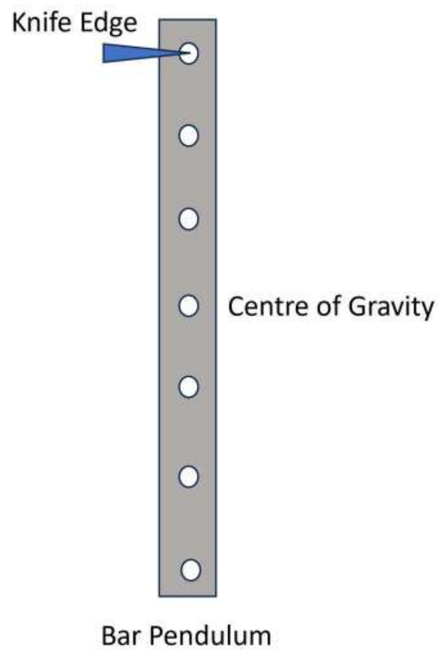

Figure 1: Schematic diagram of the Bar Pendulum setup.

Resources required: -

S. No.	Name of equipment	Specifications	Quantity	Remark
1	A uniform bar pendulum	About 1 meter long with holes drilled at equal intervals along its length	1	
2	A knife edge	With a rigid wall bracket or stand	1	
3	A precise stopwatch	-	1	
4	A metre scale	-	1	
5	A spirit level	To check the knife edge is horizontal	1	

Precautions: -

- The pendulum should be displaced through an angle less than **5°**.
- The knife-edge should be sharp, clean, and free from rust.
- Oscillations should occur in only one vertical plane.
- Timing should begin only after the pendulum starts oscillating uniformly.
- Record the time for a large number of oscillations (generally 20 or 30).

- Repeat each observation at least three times.
- Use average values for calculations.
- Measure distances carefully without parallax error.
- Ensure that the support stand remains rigid during the experiment.
- Do not apply any external force while releasing the pendulum.

Experimental Procedure: -

1. Find the **centre of gravity (C.G.)** of the bar pendulum by balancing it horizontally on a knife edge. Mark the C.G. point.
2. Fix the knife edge firmly on the wall bracket.
3. Suspend the bar pendulum from the first hole near one end using the knife edge.
4. Give the pendulum a small angular displacement and release it gently. Allow it to oscillate freely in a vertical plane.
5. Wait until the oscillations become steady. Then measure the time taken for **20 complete oscillations** using a stopwatch.
6. Measure the distance $l$between the point of suspension and the centre of gravity using a metre scale.
7. Repeat the same procedure for each hole on both sides of the centre of gravity.
8. Calculate the **time period (T)** for one oscillation for each hole using:

$$T = \frac{\text{Time for 20 oscillations}}{20}$$

9. Plot a graph with **distance coordinate** on the **X-axis** and **time period (T)** on the **Y-axis**.
10. Draw a horizontal line parallel to the X-axis so that it intersects the graph at four points.
11. Measure the distances **AC** and **BD** from the graph.
12. Calculate the effective length using:

$$L = \frac{AC + BD}{2}$$

13. Read the corresponding value of the **time period (T)** from the graph.
14. Calculate the **acceleration due to gravity (g)** using the given formula.
15. Compare the experimental value of **g** with the standard value and record the result.

Observation Table: -

Least count of the stopwatch: ……… seconds

Total number of oscillations recorded per hole: ……….

Hole No.	Distance of point of suspension from CG, l (cm)	No. of Oscillations	Time for 20 Oscillations, t (s)	Time Period, T = t/20 (s)
1				
2				
3				
4				
5				
6				
7				
.				
.				
.				
.				

Graph: -

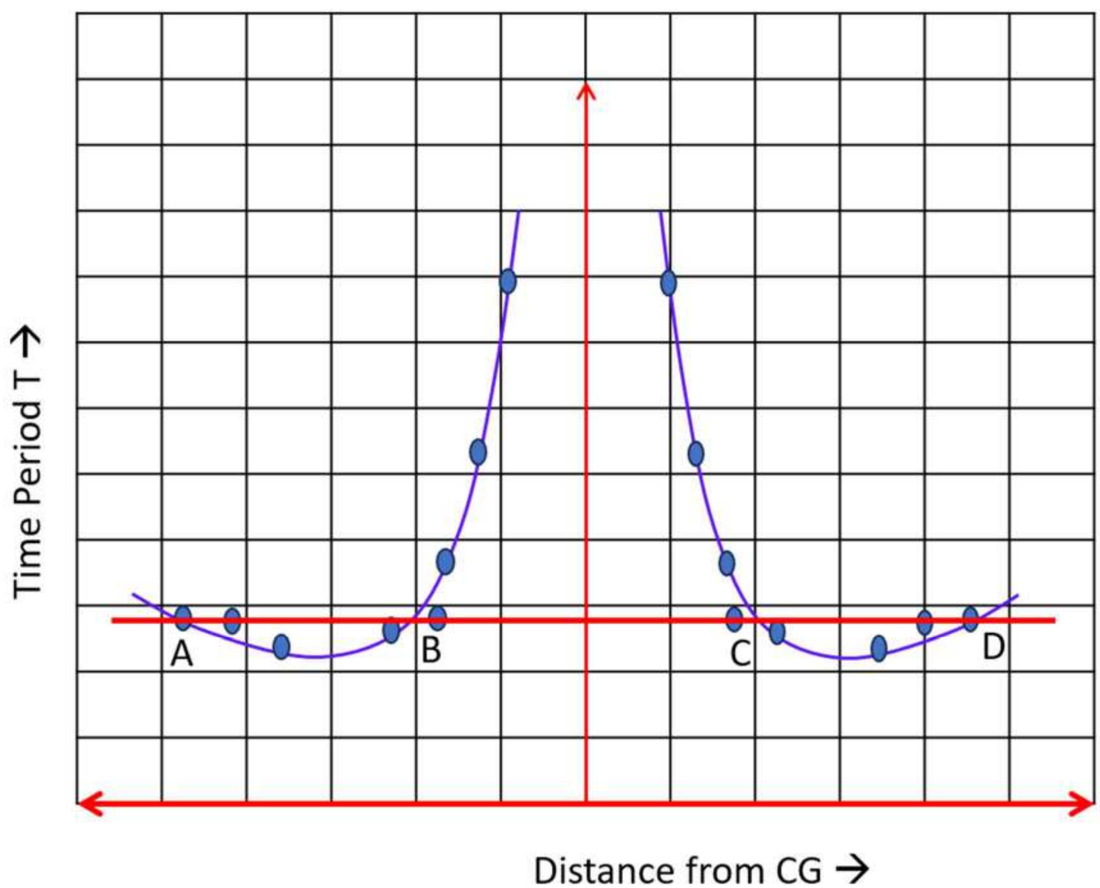

Figure: Graphical representation of Time Period (T) vs. Distance Coordinate

Calculations:

From the plotted graph:

$L = \frac{AC+BD}{2}$ = ……. and

T = ………………… (Value of T at the point of intersection of drawn horizontal line at the axis along time period)

Calculation for 'g':

Using the formula: $g = \frac{4\pi^2 L}{T^2}$

Substituting the obtained graphical values:

g = …………..

Results

The acceleration due to gravity (g) determined experimentally using the bar pendulum is found to be ……….. cm/s² (or ……… m/s²).

Interpretation of Results: -

$$\% \, Error = \frac{Calculated\,Value - Standard\,Value}{Standard\,Value}$$

= …………

Conclusion: -

The experiment was successfully conducted, and the objectives were met. By employing a bar pendulum and utilizing graphical analysis, the acceleration due to gravity was determined with a high level of precision. The symmetrical nature of the plotted graph verified the theoretical behavior of a compound pendulum. Extracting the mean equivalent length (L) and time period (T) directly from the graphical intersections effectively minimized individual observational errors, demonstrating the robustness of this classical experimental method.

Recommendations

To improve the accuracy of future experiments

- It is recommended to conduct the setup in an environment with minimal air drafts to reduce air resistance.
- Utilizing optical or laser-based photogate timers instead of manual stopwatches would significantly eliminate human reaction time errors, which are the primary source of the 1.7% deviation observed.
- Furthermore, Ensuring the knife-edge is perfectly honed and leveled using a precise spirit level before taking readings will minimize frictional damping and further refine the results.

Assessment Scheme /Rubrics (Process & Product):

S.N.	Scale ⇨ / Criteria ⇩	Poor	Satisfactory	Good	Excellent
1	**Understanding of Experiment**	Shows little understanding of the aim and theory of the experiment.	Basic understanding of the aim but explanation is incomplete.	Good understanding of the aim and theory with minor gaps.	Demonstrates clear and thorough understanding of the aim and underlying theory.
2	**Experimental Procedure & Handling of Apparatus**	Unable to follow procedure properly; improper handling of apparatus.	Follows procedure with guidance; handling of apparatus needs improvement.	Performs experiment correctly with minimal guidance.	Performs experiment independently with proper handling of apparatus.
3	**Observation & Data Recording**	Observations are incomplete or incorrect; data not properly recorded.	Records basic observations but with some errors or missing details.	Observations recorded correctly with minor mistakes.	Observations are complete, accurate, and systematically recorded.
4	**Graph / Calculations / Analysis**	Graphs or calculations missing or incorrect.	Graphs or calculations attempted but contain noticeable errors.	Graphs and calculations mostly correct with minor errors.	Graphs, calculations, and analysis are accurate and clearly presented.
5	**Neat and Clean Reporting of Practical Record**	Record is untidy with overwriting and missing diagrams or sections.	Record is somewhat neat but contains formatting or labeling issues.	Record is neat with properly drawn diagrams and organized content.	Record is very neat, well organized, and professionally presented.
6	**Viva / Conceptual Questions**	Unable to answer basic questions related to the experiment.	Answers some questions but lacks clarity in concepts.	Answers most questions correctly with reasonable explanation.	Answers confidently with clear conceptual understanding.
7	**Precautions**	Not known	Known but not understand	Known and understand	Known, understand and also know the importance
8	**Safety measures**	Doesn't follow	Follow but reason is not known	Follow and reason is known	Follow known and understand
9	**Team work ability**	Doesn't participate and perform the experiment	Perform but not interact with group	Perform and participate	Perform, participate, lead actively