Kuwait University

Physics Department

LABORATORY MANUAL

General Physics Lab I

PHYS 105 & 125

Year 2024-2025

Prepared by:

Written and Edited by:
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PHYS 105 & 125

LABORATORY COURSE OUTLINE

COURSE NUMBER: **PHYS 105 & 125**
COURSE TITLE: **General Physics Lab I**
CREDITS: **(0-3-1)**
PREREQUISITES: **PHYS 101 (Concurrent)**
Catalogue Description: Experiments in instrumentation, measurements, mechanics and optics.

LEARNING & TEACHING METHODS

- During each three-hour experimental session, students are obliged to perform the experiment, do the data analysis, interpret of results, prepare and submite the lab report in its final form.

- Ten experiments from the following list (illustrated below), or a combination of these, will be preformed by each student, in group of 2 to 3.

- The active participation and diligence shown by students in handling instruments and performing the practical work, as well as the degree of leadership in the group work, will be assessed by the instructor through observation and communication.

- In the first week of each semester orientation workshop will be held for students.

- An experimental final exam will be held at the end of the term.

OBJECTIVES

1. To enhance the understanding level of concepts in mechanics.
2. To become acquainted with the related instrumentations and experimental techniques.
3. To develop skills in communication and ability to work in groups.
4. To enhance ability in experimental design, data and error analysis and report writing.
5. To gain skills in safety requirements in handling electrical components.

LEARNING OUTCOMES

Upon the completion of the laboratory course students should be able to

1. Acquire knowledge of experimental techniques related to the concepts of mechanics;
2. Gain experience in proper data collection methods graphical representation of data, data analysis and interpretation of results.
3. Develop analytical and critical thinking abilities.
4. Work in teams.

RESOURCES

1. Laboratory manual.
2. An introduction to Error Analysis, The Study of Uncertainties in Physical Measurements (2^{nd} Edition, 1997), John R. Taylor (Publisher: University Science Books).
3. University Physics (15^{th} Global Edition, 2020), Young & Freedman (Publisher: PEARSON).
4. Physics (8^{th} Edition, 2014), D. Giancoli (Publisher: Adeson).

LABORATORY SESSIONS FOR PHYSICS 105.

	Experiment	Essential Physical Concepts
1	Pre-Lab Session	Error Analysis and how to write a lab report
2	Measurements of Density	Mass, weight, and volume
3	Kinematics of one dimensional uniformally accelerated motion.	Both Displacement and Velocity as functions of time
4	Determination of Acceleration due to Gravity	Free fall experiment and Simple pendulum experiment
5	Projectile Motion	Range Determination versus Angle
6	Static Equilibrium of Forces and Force Table	Measuring Hook's constant, and resolving of forces
7	Roller Coaster	Conservation of Mechanical Energy
8	Explosion and Elastic Collision	Conservation of linear momentum. and kinetic energy in elastic collisions.
9	Torque	Parallel and Non-Parallel Forces
10	Rotational Motion I	Kinematics of rotational motion.
11	Rotational Motion II	Work-Energy theorem.
12	General Revision	
13	Final Exam	

LABORATORY SESSIONS FOR PHYSICS 125.

	Experiment	Essential Physical Concepts
1	Pre-Lab Session	Error Analysis and how to write a lab report
2	Measurements of Density	Mass, weight, and volume
3	Kinematics of one dimensional uniformally accelerated motion.	Both Displacement and Velocity as functions of time
4	Determination of Acceleration due to Gravity	Free fall experiment and Simple pendulum experiment
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6	Static Equilibrium of Forces and Force Table	Measuring Hook's constant, and resolving of forces
7	Roller Coaster	Conservation of Mechanical Energy
8	Explosion and Elastic Collision	Conservation of linear momentum. and kinetic energy in elastic collisions.
9	Torque	Parallel and Non-Parallel Forces
10	Determination of the Velocity of Sound	Resonance Phenomenon
11	The Human Arm	
12	General Revision	
13	Final Exam	

LABORATORY REPORT SUBMISSION

Lab reports must be written individually and submitted **at the end of each lab session**. Penalties will be imposed for late submissions as follows: **deduction of 10%** of the lab marks for each late day up to a maximum of 3 days.

LAB REPORTS ASSESSMENT

The evaluation components for each experiment will be:

Lab report (Average):	40%
Student Attendance:	5%
Oral discussion:	5%
Quizes:	10%
Final Exam:	40%

Lab reports should consist of three elements in the following order: Statement of Objectives, Data and Analysis of results, Discussion and Conclusion.

Evaluation of the lab reports will be carried out according to the criteria stated in the laboratory Report Assessment Form.

ATTENDANCE REQUIREMENTS

Attendance in all lab sessions is mandatory. The assigned marks for attendance will be deduced from the grade of any lab session skipped by the students. **Late students how attend to the laboratory hall after 20 minutes (or more) from the begining of the lab session, will not be allowed to enter the laboratory hall and will be recorded absent**.

PLAGIARISM

Plagiarism is a serious academic offense. Put simply plagiarism is an action where a person claims the work or ideas of other people as his won with the intention to deceive. Examples of plagiarism are:

- The use of published or unpublished work of others either as whole or in parts (such as paragraphs or sentences), which includes books, journal articles, theses, websites, etc. without proper acknowledgment or referencing or without the use quotation marks.

- Paraphrasing closely the work of others either as a whole or in parts without proper referencing.
- Copying computer files without proper acknowledgments.
- Use or submission of computer programs written by others without authorization.
- Claiming as your own work executed for you by other person or agency.
- Scattering one's own comments through a text that has been substantially lifted from another source.


LAB
SAFETY
RULES
THINK
SAFETY
No Food
No Smoking
Don't eat, drink or smoke inside the labs.
عدم تناول الطعام أو الشراب أو
التدخين أثناء التواجد في المختبر.
Protective care
Wear safety goggles, gloves, and lab coat (when necessary).
إرتداء نظارات السلامة،أو القفازات
أو معطف المختبر (عند الضرورة).
Proper Supervision
Follow all the instructions given by your lab Instructor.
إتباع جميع تعليمات مشرف المختبر.
Be Attentive
Never touch electrical connections, unshielded electrical wires and sharp objects
عدم لمس التوصيلات أو الأسلاك
الكهربائية غير المحمية والأدوات الحادة.
Your Stuff
Keep your personal items inside the student's shelves.
الاحتفاظ بالأغراض الشخصية داخل
الرفوف المخصصة للطالب.
Handle Carefully
Never Insert anything into electrical sockets or devices.
عدم إدخال أي شيء في المقابس
أو الأجهزة الكهربائية.
Safety First
Know the location of the safety equipment and the emergency numbers.
تحديد مواقع معدات السلامة،
وحفظ أرقام الطوارئ.
Clean-up
Switch OFF all devices and keep your work-space neat and tidy before leaving
إيقاف تشغيل جميع الأجهزة، والحفاظ على
منطقة العمل نظيفة ومرتبة.
Attention! In case if there is an emergency alarm , you have to evacuate the lab immediately.
انتبه! في حالة سماع صوت صافرة الإنذار يرجى إخلاء المختبر على الفور.

Laboratory Report Assessment Guide

Prepare lab work:

- Read the experiment sheet.
- Prepare for a oral discussion during the lab session.

Guidelines to Lab Report writing and marking scheme:

- **Title page**
  Use the cover pages provided to you at the end of the manual to write your name, the name of your laboratory partner, the date, the section number of the laboratory, and the instructor's name.
- **Statement of Objectives:** [1 Marks]
  You should outline the objectives of the experiment in your own words.
- **Data and Analysis of Results:** [6 Marks]
  - ∗ Concise presentation of data and results with proper calculations and units.
  - ∗ Properly scaled and titled graphs with acurate slope celaulations and graph analysis.
  - ∗ Error analysis.
- **Discussion and Conclusion:** [3 Marks]
  - ∗ The student must describe what his/her results are, and compare them with the accepted values.
  - ∗ Discuss possible methods to reduce uncertainties.
  - ∗ Draw conclusions (by explaining the meaning of the experiment and the implications of the results).

- **References**
  Proper citation of references must be made whenever called for. Improper or inadequate citation of references can lead to a deduction of up to 10% of the total grade.

- **Report Presentation:**
  The report must be **neatly** presented.

Total Mark: 10

Error analysis

Error is known to be the difference between a calculated or observed value and the true value. All experimental uncertainties are due to the presence of two types of experimental errors: **systematic errors** and **random errors**. The difference between random errors and systematic errors can be shown by repeating the measurement of a physical quantity several times under the same conditions. Random errors are statistical fluctuations or variations in the measured data produced by the experimenter's inability to take the same measurement in exactly the same way to get exactly the same reading. Therefore, the readings will be spread about the true value. See Figure 1 (a). Systematic errors, on the other hand, are reproducible inaccuracies that causes the measurements to constantly be in the same direction (either too high or too low). They are mostly due to defects in the measuring devices which make them continually present throughout the entire experiment. Therefore, the readings will always be displaced far from the true value see Figure 1 (b). For that reason, systematic errors are difficult to detect and cannot be analyzed statistically.

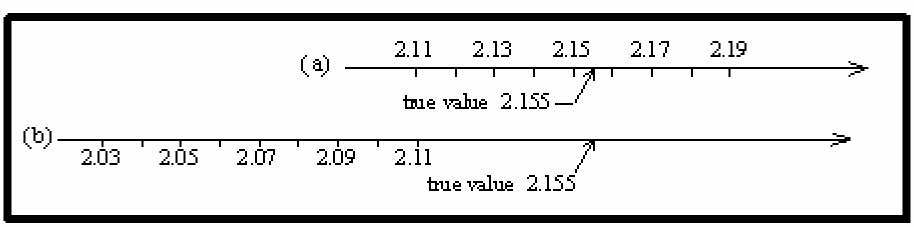


Figure 1: (a) A set of measurements taken with random errors only.
(b) shows a set of measurements with both systematic and random errors.

Statistical analysis of random errors

Assume x represents a physical quantity, such as the period of a simple pendulum, that is measured n times.

- **Calculating the Mean Value**

  For this set of measurements, to compute the mean value of your result (also known as the **Average value**) you should use the following equation :

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

  where x represents the physical parameter measured, n equals the number of measurements, and x_i is the i^{th} measured value.

- **Determining the Standard Error**

  To compute the standard error of the measurements, we have to introduce the **standard deviation** (σ_x). The term refers to a statistical quantity which tells you how your measurements are spread around the mean value. If the standard deviation is small then the spread is also small, which indicates that your data hold great deal of accuracy.

  The following law is used to calculate the standard deviation:

$$\sigma_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^{i=n} (x_i - \bar{x})^2} \tag{2}$$

$$= \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + ... + (x_n - \bar{x})^2}{n-1}}$$

  Finally, the standard deviation is used to calculate the **standard error** ($\sigma_{\bar{x}}$), as follows: The uncertainty or the standard error in the mean value is defined as:

$$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{n}} \tag{3}$$

  The result to be reported from any measurement is

$$\bar{x} \pm \sigma_{\bar{x}} \tag{4}$$

Using the Pocket Calculator

The same analysis used to compute the mean value, standard deviation, and the standard error can also be done simply using the pocket calculator. It is not intended to use the calculator to preform the known binary operations such as addition or subtraction. What is meant by using the calculator is to use the statistical mode ,also known as **"SD"** mode, in your calculator and the subroutines which are already programmed in your calculator to compute the mean value and the standard deviation required. A simple procedure is discussed to illustrate such a use of the pocket calculator by your instructor.

Example:

For the following set of measurements of the period (T) of a simple pendulum calculate the mean period $\bar{T}$ according to Equation 1. Use the calculator to get the mean period $\bar{T}$. Also calculate the standard deviation for the period σ_T according to Equation 2. Use the calculator to get the standard deviation σ_T. Finally, calculate the standard error $\sigma_{\bar{T}}$ using Equation 3.

Table

quantity	T_1	T_2	T_3	T_4	T_5	T_6
T_i (s)	1.430	1.368	1.402	1.324	1.389	1.422
(T_i - $\bar{T}$) (s)						
$(T_i - \bar{T})^2$ (s^2)						

$\bar{T}$ (The Mean Value By equation 1) =...,

σ_T (The Standard Deviation By equation 2) =...,

$\sigma_{\bar{T}}$ (The Standard Error By equation 3) =..,

Significant figures

The term **significant figures** refers to the meaningful ”reliable” digits shown in a measured or calculated value. The number of significant figures in a measured value is determined, among other factors, by the least count of the measuring tool, which means the smallest unit in the tools scale.

For example, if the thickness of a book is to be measured using a ruler, the measurement could be 2.6 cm, which consists of 2 significant figures. Whereas if the same measurement is carried out using a vernier caliper the result might be 2.615 cm which consists of 4 significant figures.

The least digit (the most right digit) in a measured value is referred to as uncertain. The reason is when taking a measurement, usually the reading is approximated to the nearest lest count. For instance, for the reading taken by the ruler (2.6 cm) the digit 6 is uncertain whereas in the reading taken by the vernier caliper (2.615 cm) the digit 5 is uncertain. When using numbers having uncertainties to compute other numbers, the computed numbers are also uncertain. The general rules to specify the number of significant figures are as follows:

Multiplication or division

When numbers are multiplied or divided the number of significant figures can be no greater than in the number with fewest significant figures.
Examples:

$$\frac{0.745 \times 2.2}{3.885} = 0.42$$

$$1.32578 \times 10^{7} \times 4.11 \times 10^{-3} = 5.45 \times 10^{4}$$

Addition or subtraction

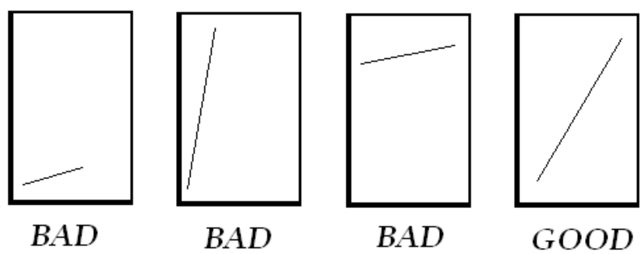
When numbers are added or subtract, the number of significant figures in the result is determined by the number with the fewest digits to the right of the decimal point.
Example:

$$27.153 + 138.2 - 11.74 = 153.6$$

Graphical analysis

A graph is a diagram consisting of a line which shows the variation of two quantities relative to each other, in lab terminology we say *plot y versus x*. In order to plot a good graph you should note the following:

- Use a sharp pencil or pen.
- Draw your graph on full page of graph paper. A compressed graph will reduce the accuracy of your graph.



- Give the graph a title.
- The dependent variable should be plotted along the vertical or y axis and the independent variable should be plotted along the horizontal or x axis.
- Choose a suitable scale for both variables. It is not essential to have the same scale units for both quantities, but avoid scale factors like 3 or 7. The scale should neither be too wide nor too narrow. In any graph you should give for both axes the proper scale, the physical quantity plotted and its unit.
- If the relation between the two variables begins from zero, then zero must be taken as the origin on both scales. Otherwise the origin on both axes should represent a quantity little less than the smallest value of the corresponding variable.
- Label axes and include units.

- Draw a smooth free-hand curve to pass through as many plotted points as possible. If a smooth curve does not pass through all the points, those left out should lie evenly about it.

Linear graph

A straight line graph has a constant slope. The slope is the change in the value of the variable plotted on vertical axis (y axis) divided by the corresponding change in the value of the variable plotted on the horizontal axis (x axis). The slope is determined by selecting two well separated points **A** and **B** on the line. Record the values of x_A, y_A and x_B, y_B. Then the slope m is given by:

$$m = \frac{y_B - y_A}{x_B - x_A} \tag{1}$$

The general equation of a straight line not passing through the origins

$$y = mx + C \tag{2}$$

Where m is the slope and C is the intercept on the y axis ($x = 0$). The intercept on the x axis ($y = 0$) can be obtained from

$$x = -\frac{C}{m} \tag{3}$$

Kuwait University Physics Department
Physics 105 & 125

Measurements of Density

Objectives

In this experiment the students will be introduced to the most frequently used measuring devices. Those devices are used for determining the length, diameter, and mass of a set of cylindrical objects. The main objective of this experiment is to show the students how to use those measuring devices properly to determine the density of the cylindrical objects and compare it to the accepted values of the density of the metals.

Equipment list

- Four cylindrical objects of different sizes made from the same material (aluminum, Maple wood, Phenolic, PVC, or Acrylic).
- Measuring devices:

  the *Micrometer Screw Gauge* (Figure 2).

  the *Vernier Caliper* (Figure 3, 4).

  the *Laboratory digital balance.*

Introduction

A unit of measurement is a definite magnitude of a physical quantity that is used as a standard for measurement of the same physical quantity. Any other value of the physical quantity can be expressed as a simple multiple of the unit of measurement. For example, length is a physical quantity. The “meter” is a unit of length, used in global standard International System of Units (SI), and it represents a definite predetermined length. When we say 10 meters (or 10 m), we actually mean 10 times the definite predetermined length called "meter". This is also true with mass, time, and all other physical quantities.

Figure 1. below shows different types of measuring devises all of which are used to determine the length. Each measuring device has its won accuracy and used according to the shape and size of the object that needs to be measured. The metric roller (Figure1. A) used to determine the length of large curved objects, the metric wheel (Figure 1. B) is used with field measurements, and the metric laser pointer (Figure 1. C) is used for measuring the height of lengths of very large objects such as bridges and mountains.

Figure 1. Various types of measuring devices used for length measurements

In our experiment we will determine the dimensions of much smaller objects like cubes and cylinders, thus we will be introduced to other measuring devices designed specifically for this type of measurements with higher degree of accuracy and precession.

Theory

Density ρ of any substance is defined as the mass m of a unit volume of that substance. The obvious way of finding it is by determining the mass of a known volume of the substance and dividing this mass by the volume

$$\rho = \frac{m}{V} , \tag{1}$$

The volume of any solid which has a simple geometric form may be determined from its dimensions; which, if the body is small, are most conveniently measured by a **Vernier Caliper** and a **Micrometer Screw Gauge**. The mass; however , is found by the use of the laboratory triple balance.

The **micrometer screw gauge**, (Figure 2), is most convenient for the accurate measurement of short lengths. The object is placed between the end of the screw and the anvil. The distance through which the screw travels is measured by two scales:

- **Main Scale** which is divided into millimeters on the lower part and half millimeters on the upper part.
- **Rotating Scale** which is divided to (50) divisions each of which represents (0.01 mm).

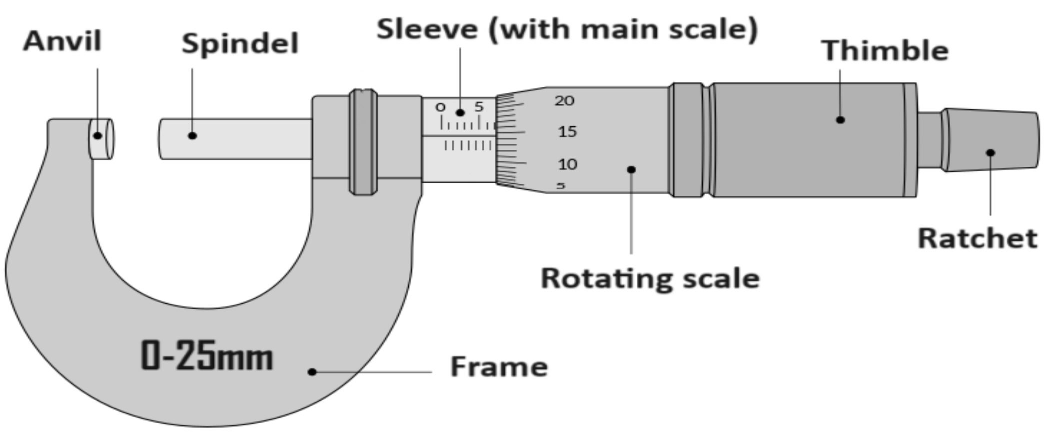


Figure 2. Micrometer Screw Gauge

The two scales are related to each other such that one complete revolution of the rotating scale equals half a millimeters on the main scale.

The **Vernier Caliper**, (Figure 3), is considered also as a convenient device for accurate measurement of short lengths of objects. The object placed between the jaws. The distance through which the jaws travel is measured by two scales:

- **Main Scale** which is divided into inches on the upper part and centimeters on the lower part.
- **Vernier Scale** which is divided to (20) divisions each of which represents (0.005 cm).

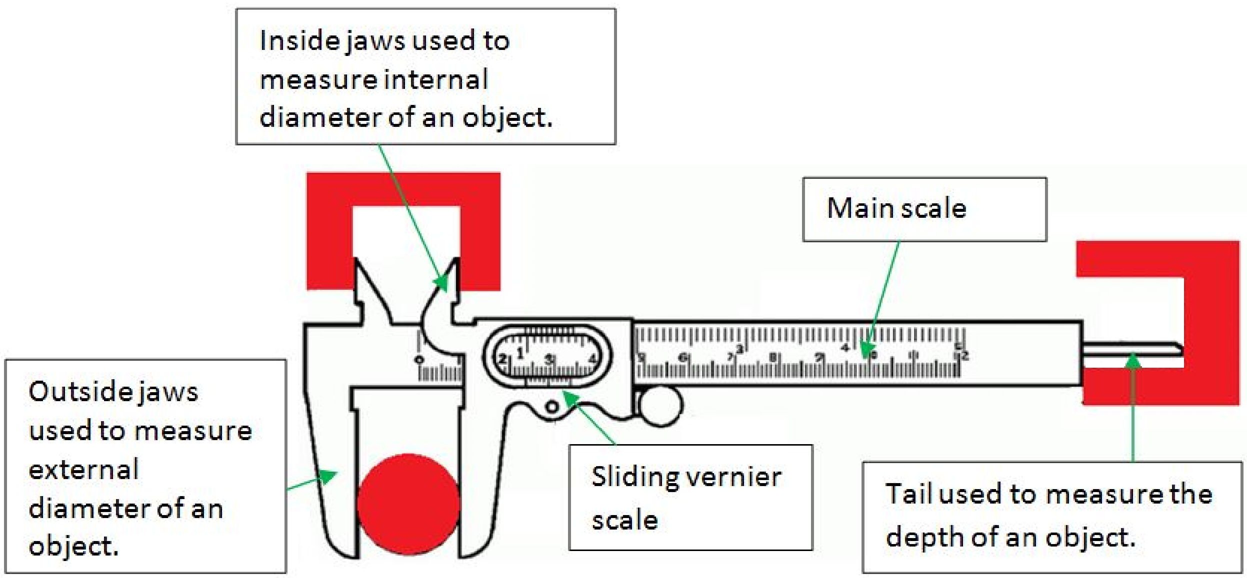


Figure 3. Vernier Caliper

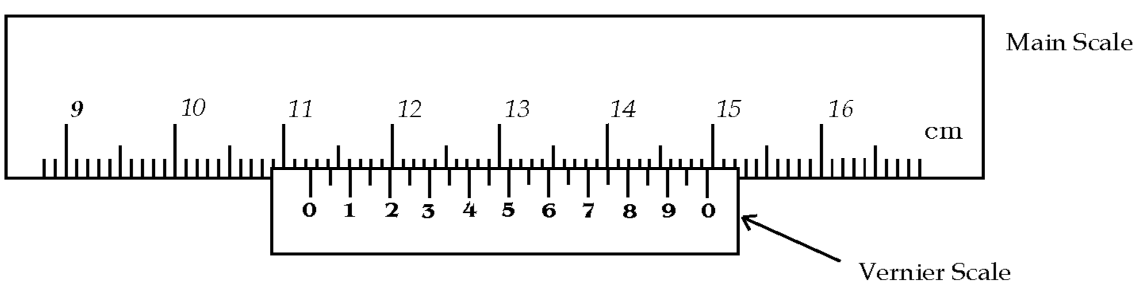


Figure 4. Magnified view of the Vernier Caliper

How to take readings from Micro-meters

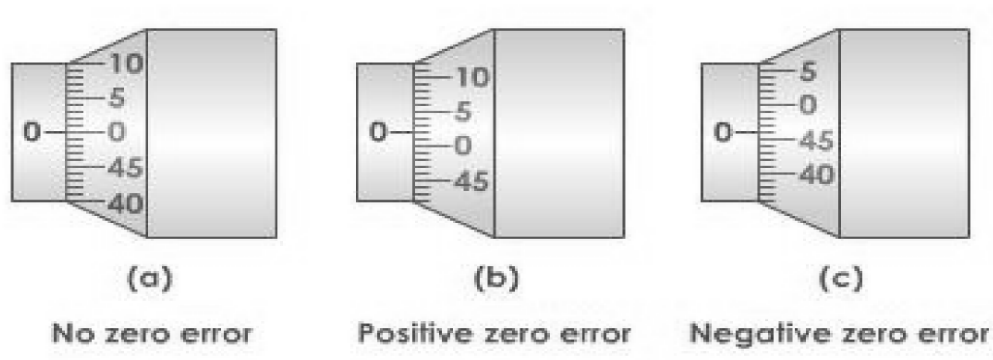


Figure 5:(a). has no zero error and hence zero correction (Z.C)=0, (b). has a zero error of +2 and hence zero correction (Z.C)=-2, (c). has a zero error of -4 therefore its zero correction (Z.C)= +4

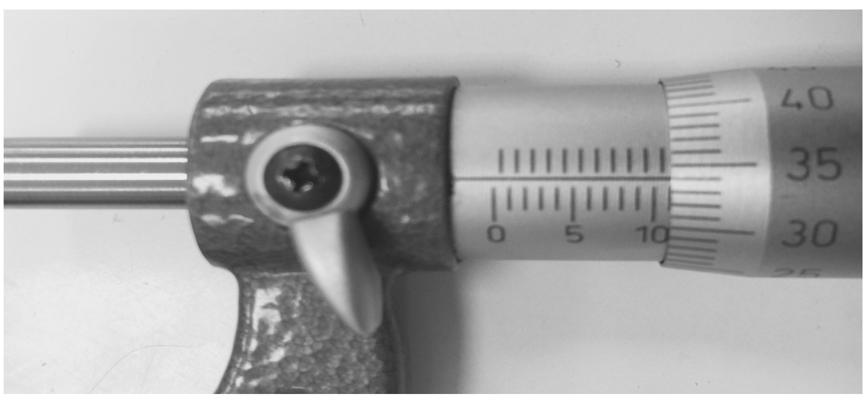
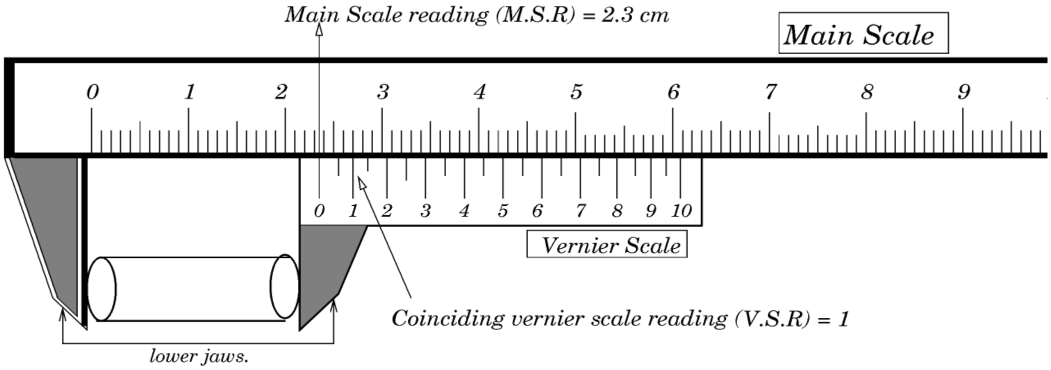


Figure 6. Assuming that zero correction (Z.C)=+5. In this figure Main scale reading **(M.S.R)**=10.5mm, and the rotation scale reading **(R.S.R)**=34, thus the total reading is:

$$T.R = M.S.R + \frac{R.S.R}{100}$$

$$T.R = 10.5 + \frac{34 + 5}{100} = 10.89mm$$

How to take readings from Vernier Caliper



cylindrical objects should be placed between the lower jaws of the vernier caliper, as shown in the figure. The Main scale reading ($M.S.R$) should come from main scale. To take the ($M.S.R$), you should carefully watch, where the **zero** of the vernier is meeting the main scale. In the picture shown above you can see that 0 (*zero*) of the vernier scale meets the main scale between 2.3 and 2.4. So your $M.S.R$ will be 2.3 and **not 2.4**. Remember you will take the reading which is before zero always. The Coinciding vernier scale reading ($V.S.R$) should come from vernier scale. To take the ($V.S.R$) you should look for the first reading from the vernier scale which exactly coincides with any of the main scale reading. In the picture shown reading **1 of the vernier** fulfills the requirement. So $V.S.R$=1. Remember: the Least Count (L.C) for the all the vernier calipers in our lab is equal to 0.01 cm. So finally the total reading $T.R = M.S.R + (\frac{V.S.R}{100}) = 2.3 + \frac{1}{100} = 2.31cm$

Procedure

1) Use the micrometer screw gauge to **measure** the diameter (d) of the cylindrical objects. **Record** your data in Table (II).

2) Use the vernier caliper to **measure** the length (l) of the cylindrical objects. **Record** your data in Table (II).

3) Use the laboratory triple balance to **measure** the mass (m) of the cylindrical objects. **Record** your data in Table (II).

4) **Calculate** the volume for each cylindrical or rectangular object using the measured values of diameter and other dimensions according to the equation stated in Table (I).

5) **Calculate** the density (ρ) for each piece.

6) **Compute** the average value of the density ($\bar{\rho}$).

7) **Calculate** the standard error ($\sigma_{\bar{\rho}}$)of your results.

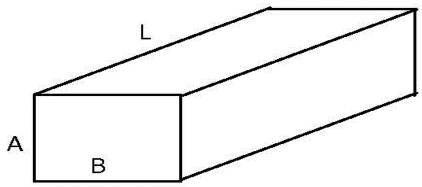
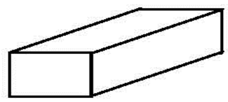
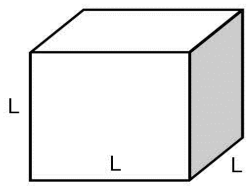
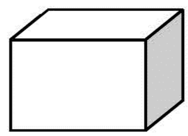
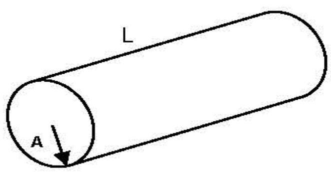
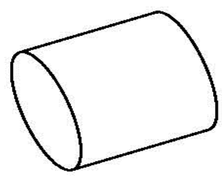
8) Use you data on Table (II) to **plot** a graph of the mass m (y-axis) of each cylindrical rectangular object versus its volume V (x-axis). According to equation (1) the graph should be a straight line through the origin. **Get** the density ($\bar{\rho}$) from the slope of this line.

9) **Repeat** steps (1) to (7) for a different set of cylinders and **record** your data in Table (II) below.

10) Use you data on Table (II) to **plot** a graph of the mass m (y-axis) of each cylindrical object versus its volume V (x-axis). **Get** the average density ($\bar{\rho}$) from the slope of this line.

11) **Compare** the measured density with the accepted values for the density of metals.

Table I. Geometrical Shapes and their corresponding volumes

Shape and dimension		Volume
		V = A$\times$ B $\times$ L
		V = L^3
		V = $\pi A^2 \times L$

Kuwait University

Course / Section:________

Student Serial Number:

Physics Department

Date: [ ] [ ] [ ]
day month year

Experiment ( ): ______________________________
____

*Student name:*______________________ *Student number:*___________

Instructor name: ______________________

Partners: __________________________
____
____

Total Mark

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Measurement of Density

Objectives:

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Table II. Measurements of Density

Shape	Lengths using Vernier Calipers(L)	Diameter using micrometer (D)*	Volume (V)	Mass (m)	Density (ρ)
Material	T.R = M.S.R + $\frac{(V.S.R)}{100}$	T.R = M.S.R + $\frac{(R.S.R+Z.C)}{100}$	$From\ Table$ 1.	m	$\rho = \frac{m}{V}$
....	( )	( )	( )	( )	( )
Object-1					
Object-2					
Object-3					
Object-4					

Remarks:

*The units of measurements of diameter (D) should be converted from (mm) to (cm)

Abbreviations:

T.R = Total Reading   M.S.R = Main Scale reading   V.S.R= Vernier Scale Reading

R.S.R = Rotating Scale Reading   Z.C = Zero Correction

Kuwait University **Physics Department**

Physics Lab 105 *Student Number:*

Student Name: *Date:*

Measurement of Density

Standard deviation and standard error calculation:

Find the average value of density for the cylinders i.e,

$$\overline{\rho} = \frac{\rho_1 + \rho_2 + \rho_3 + \rho_4}{4} = \text{...}$$

Complete the following table and report the result in the form $\bar{\rho} \pm \sigma_{\bar{\rho}}$.

quantity	ρ_1	ρ_2	ρ_3	ρ_4
ρ_i				
$(\rho_i - \overline{\rho})$				
$(\rho_i - \overline{\rho})^2$				

standard deviation:

$$\sigma_\rho = \sqrt{\frac{1}{n-1}\sum_{i=1}^{i=n}(\rho_i - \overline{\rho})^2} = \text{..........................}$$

standard error($\sigma_{\overline{\rho}}$).

$$\sigma_{\overline{\rho}} = \frac{\sigma_\rho}{\sqrt{n}} = \text{...................................}$$

RESULT : $\bar{\rho} \pm \sigma_{\bar{\rho}}$= ....

Determine the percentage error in the density (ρ):

$$\left|\frac{\rho_{theory} - \rho_{calculated}}{\rho_{theory}}\right| \times 100 = \frac{\text{.....................} - \text{...................}}{\text{......................}} \times 100 = \text{...................}\%$$

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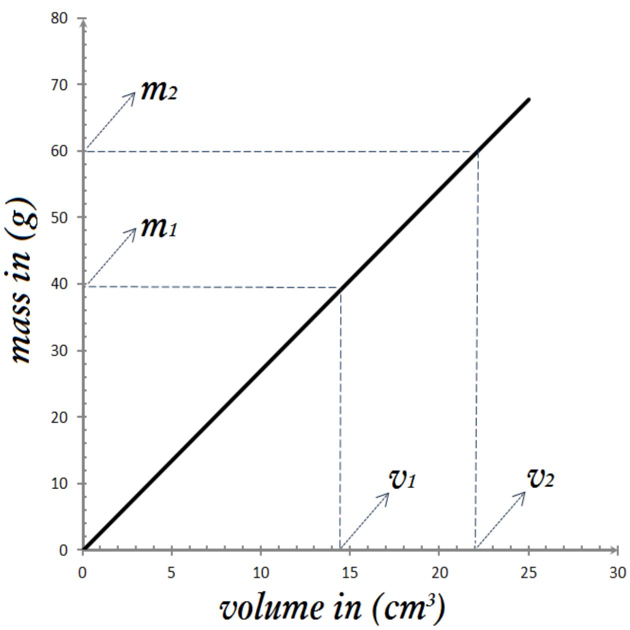
Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Measurement of Density

Plot a graph of mass versus volume and determine the density of the material used:



$$Slope = \frac{m_2 - m_1}{v_2 - v_1} = \frac{(\quad) - (\quad)}{(\quad) - (\quad)}$$

Density = Slope = ...

Discussion and conclusion:

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Kuwait University Physics Department
Physics 105 & 125

Kinematics of one dimensional motion with constant acceleration

Objectives

The main objective of this experiment is to study the displacement as a function of time for a one-dimensional uniformly accelerated motion; and to determine the instantaneous velocity of the moving object at a given position by utilizing the displacement (Δx) versus time (t) graph.

Equipment

- 2 m air track with a glider, mass pieces, and small flag.
- Smart timer with two Accessory Photo-gate heads.
- Air pump.

Theory

Part A:

If an object is set to move from rest under the action of gravity on an inclined frictionless track, its displacement Δx as a function of time t is given by

$$\Delta x \;=\; v_0\, t + \frac{1}{2}\, a\, t^2 \;\;\Longrightarrow\;\; \Delta x \;=\; \frac{1}{2}\, a\, t^2. \tag{1}$$

where, $a = g\, sin\, \theta$ is the acceleration with which the object is moving and θ is the angle of inclination of the air-track. A plot of Δx versus t represents a parabolic curve as seen in Figure 1.

The instantaneous velocity v at a given time is defined as

$$v = \lim_{\Delta t \to 0} \left(\frac{\Delta x}{\Delta t}\right) = \frac{dx}{dt}. \qquad (2)$$

Equation 2 indicates that the instantaneous velocity equals the slope of the tangent to the curve of Δx versus t at a given point. See Figure 1.

Also, the velocity at the end of a displacement Δx is given as

$$v^2 = v_o^2 + 2\,a\,\Delta x. \qquad (3)$$

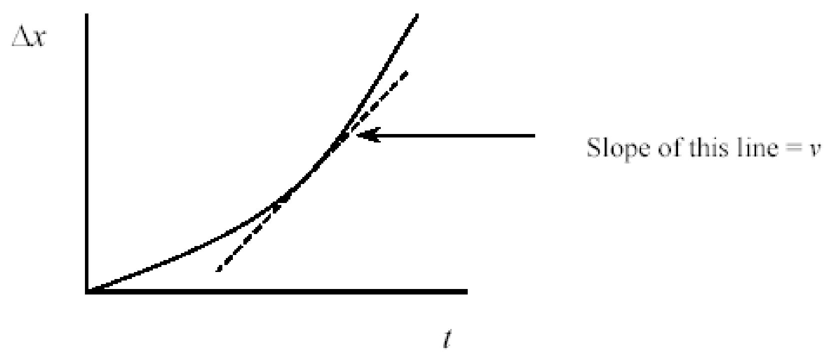

Figure 1. Displacement versus time

Procedure

1) **Make sure that the screws attached to the legs of the Air-track are screwed inward tight (so the track is horizontal)**. Now let the air-track (Figure 2) be inclined by putting 1 cm support units beneath the legs of one side of the air-track.

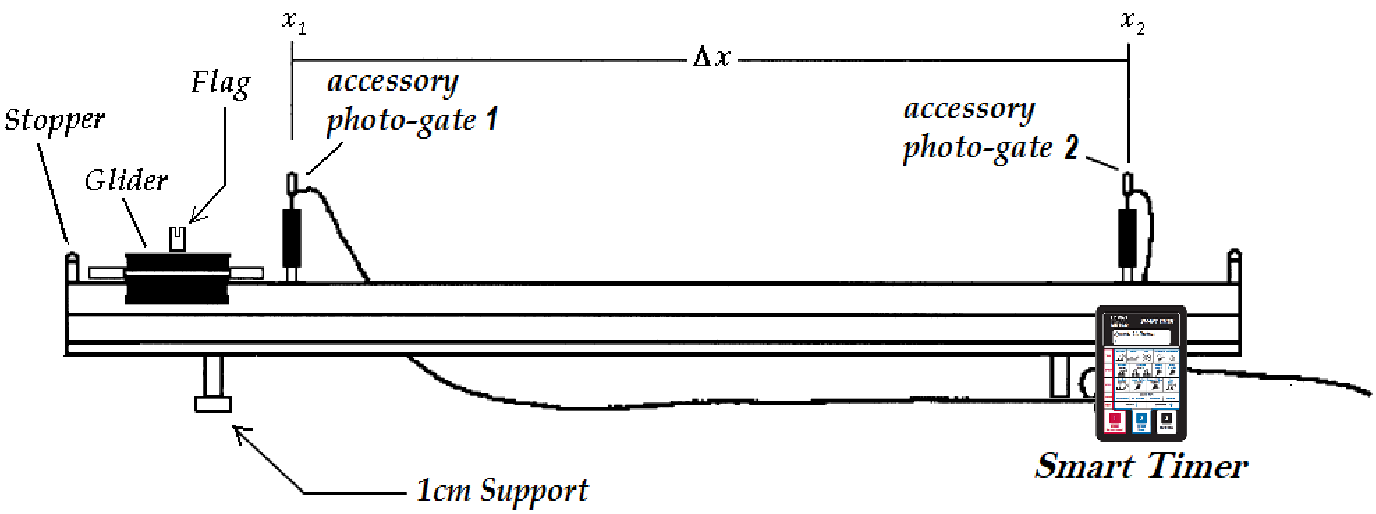

Figure 2. Air Track setup

2) **Put** the accessory photo-gate-**1** at position $x_1 = 10\,\text{cm}$ as indicated to you in **Table 1**, and the accessory photo-gate-**2** at $x_2 = 30\,\text{cm}$. **Connect** each photo-gate to its proper input channel on the Smart timer (Figure 3).

3) Using a glider with the small flag mounted on top, **adjust** the height of each photo-gate head so that the flag of the glider blocks the photo beam when it passes through.

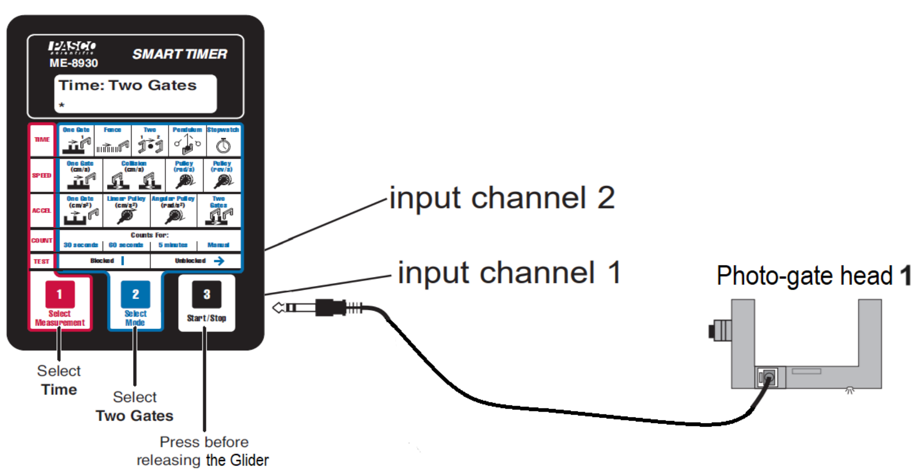

Figure 3. Smart Timer

4) On the Smart timer, **set** the select measurement (RED) button to “TIME”, **set** the select mode (BLUE) button to “Two Gates”, and **press** the (BLACK)

"Start\Stop" button to reset the timer. To confirm timer reset, (∗) will appear on the smart timer screen.

4) **Hold** the glider at the beginning of the track (such that the flag is just before the accessory photo-gate-**1**), turn on the air pump then, **release** the glider.

5) **Record** the time (t_1) in **Table 1**, and **Repeat** this step two more times.

6) On the Smart timer, **set** the select mode (BLUE) button to "One Gate", and **press** the (BLACK) "Start\Stop" button to reset the timer. To confirm timer reset, (∗) will appear on the smart timer screen.

7) **Remove** accessory photo-gate-**1** only by rotating it 90^o in the clock wise direction then, **repeat** steps 4 & 5, but **record** the measured time for Δt.

8) **Return** the accessory photo-gate-**1** to its previous position (i.e. at $x_1 = 10\,\mathrm{cm}$ then, **change** the position of the accessory photo-gate-**2** according to **Table 1**, and **repeat** steps 4-8.

9) For each Δx in the table, **calculate** the average value of time ($\bar{t}$), and ($\bar{\Delta t}$). Also, **compute** velocity $v = w/\bar{\Delta t}$ and acceleration $a = v/\bar{t}$, where $w = 0.75cm$ is the distance between two leading edges of the small flag.

10) **Plot** the relation of displacement (Δx) versus time ($\bar{t}$), then determine the slope of the tangent to the curve at the point $\Delta x = 90$ cm. (Note that $\Delta x = 90\,\mathrm{cm}$ corresponds to $x_2 = 100\,\mathrm{cm}$).

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Instructor name: _

Partners: _

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Total Mark

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Kinematics of one dimensional motion with constant acceleration

Objectives:

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Table I: Flag width w = ...(......)*

x_1 ( )	x_2 ( )	Δx ( )*	Two Gates Mode: t_1 ( )	t_2 ( )	t_3 ( )	$\bar{t}$ ( )	One Gate Mode: Δt_1 ( )	Δt_2 ( )	Δt_3 ( )	$\bar{\Delta} t$ ( )	v ( )	a ( )
10	30											
10	40											
10	60											
10	80											
10	100											
10	120											
10	140											

Remarks:

*The units of the flag width (w) and displacement (Δx) should be converted from (cm) to (m)

Kuwait University **Physics Department**

Physics Lab 105 & 125
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Student Name:
Date:

Kinematics of one dimensional motion with constant acceleration

∗ Is the acceleration constant?............, Determine its average value $\bar{a}$ = ...

∗ The slope of displacement (Δx) versus time ($\bar{t}$) graph = ...

∗ What does the slope represent? ....

....

∗ Using the average value of the acceleration ($\bar{a}$), Estimate the instantaneous velocity v at $x_2 = 100$ cm using Equation 3.

....

∗ Determine the percentage error in the instantaneous velocity v:

$$\left|\frac{v_{estimated} - v_{graph}}{v_{estimated}}\right| \times 100 \ = \ \text{...}$$

∗ Use the average value of the acceleration ($\bar{a}$) calculated above to determine the angle of inclination of the air track.

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Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Kinematics of one dimensional motion with constant acceleration

Discussion and conclusion:

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Kuwait University Physics Department
Physics Lab 105 & 125

Determination of Acceleration due to Gravity

Objectives

The aim of this experiment is to understand the concept of acceleration in general and that due to gravity in specific. To achieve this goal, the acceleration due to gravity ($\boldsymbol{g}$) is determined using two different methods. In free falling method, the kinematics of motion with constant acceleration is utilized to determine the value of ($\boldsymbol{g}$). In the second method; however, simple harmonic motion phenomenon of a simple pendulum is used and the period of this motion is analyzed. At the end of the experiment, you should be able to verify that the value of ($\boldsymbol{g}$) computed is constant and equal the accepted value within experimental error.

Equipments:

- Experimental setup for free fall (Figure 1)
- Experimental setup for simple pendulum (Figure 4)
- Smart Timer(Figure 3)
- Small steel ball (1.6 cm diameter), small wooden ball (1.6 cm diameter).
- Time of Flight Accessory.
- Measuring devices: metric Ruler.

Theory

Part A: Free Fall

A freely falling body is an object that is moving under the influence of gravity only. This object has a downward acceleration, denoted by ($\boldsymbol{g}$), toward the center of earth. In order to calculate the value of the gravitational acceleration, you will use the free fall experimental setup illustrated in Figure 1. The plastic yellow ball is fixed to the releasing mechanism of the free fall Drop Box. Allowing the ball to fall a fixed distance h toward the Time of flight Receptor Plate, the smart timer will compute the time elapsed for the ball to fall that distance.

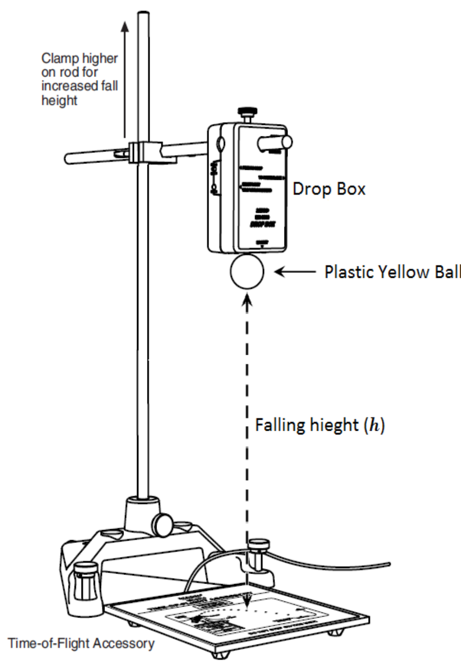

Figure 1 Free Falling Apparatus

The position of the ball, starting from rest at time $t = 0$ and undergoing constant downward acceleration along the y-direction, can be understood using the following equation

$$y(t) - y_o = -\frac{1}{2}gt^2, \tag{1}$$

where y_o is the initial position and $\boldsymbol{g}$ is the acceleration due to gravity. If h is the falling distance the body has traveled from its starting point during time t, then above equation can be written as

$$h = \frac{1}{2}gt^2 \qquad \Longrightarrow \qquad g = \frac{2h}{t^2}. \tag{2}$$

Therefore, to calculate the value of $\boldsymbol{g}$, you should study the relation between the falling distance h and t^2. Some further analysis will be carried out to check whether acceleration due to gravity is constant or not.

Part B: Simple Pendulum

The simple pendulum consists of a small bob (in theory a particle) of mass m suspended by a light inextensible thread of length l from some point about which it is allowed to swing back and forth. See Figure 2. The forces on the bob are the tension in the thread T and the weight mg of the bob acting vertically downwards (as shown in Figure 2). Resolving mg radially and tangentially at point **A** we see that the tangential component is the unbalanced restoring force acting towards the equilibrium position **O**.

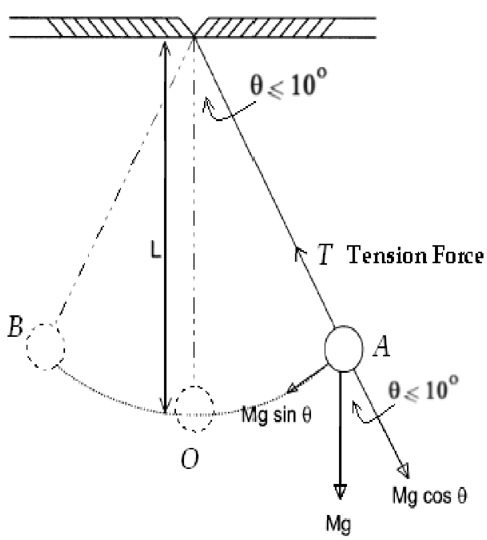

Figure 2. Simple Pendulum

When θ, the angle of the simple pendulum with the vertical, is small ($\theta \leq 10^o$) then the restoring force is proportional to θ and the period of oscillation T is constant and given by

$$T = 2\pi\sqrt{\frac{l}{g}} \quad \Longrightarrow \quad g = 4\pi^2\left(\frac{L}{T^2}\right). \tag{3}$$

where, l is the length of the simple pendulum, and $\boldsymbol{g}$ is the acceleration due to gravity. T is therefore independent of the amplitude of the oscillation and at a given place on the earths surface where $\boldsymbol{g}$ is constant; it depends only on the length l of the pendulum.

Procedure

Part A: Free Fall

1) **Set up** the free fall timer as shown in Figure 3. Use the plastic yellow ball.

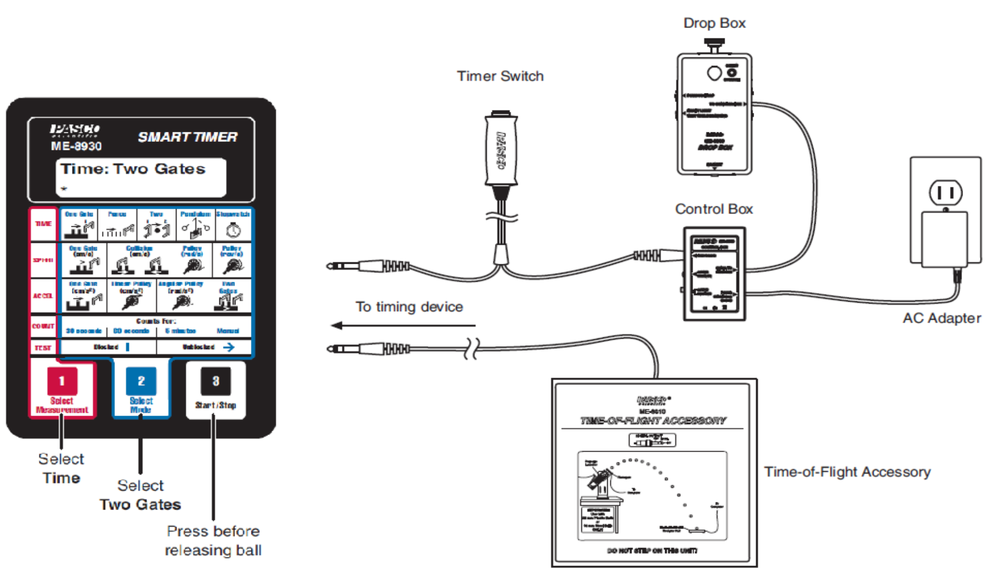

Figure 3. Experimental Setup.

2) All connections of the experimental setup has to be as indicated in Figure 3 above. **Set** the **ACTIVE/INACTIVE** switch on the control box to **ACTIVE**.

3) **Hang** the Small steel ball from the drop box magnet.

4) **Connect** the Smart Timers AC adapter to its power port and turn it on.

5) **Connect** the remaining plug of the Timer Switch to channel **1** of the Smart Timer and **connect** the Time-of-Flight pad to channel **2** of the Smart Timer.

6) On the Smart Timer, **press** the **1 Select Measurement** button once to select Time, **press** the **2 Select Mode** button several times to select Two Gates mode. and **press** the **3 Start/Stop** button. The Smart Timer will beeps and an asterisk (*) will appear on the display to indicate that it is ready to start timing.

7) Once the height (h) is set, **Press** the Timer Switch button. The ball is released from the drop box and hits the Time-of-Flight pad, the Smart Timer displays the fall time. **Record** the time of fall (t) in Table (I). **Wait** until the LED on the drop box stops blinking, **attach** the ball once again to the Drop Box and **repeat** the measurement one more time and calculate the average time of fall.

8) **Increase** the height (h) to any other different value and **repeat** the measurements made in the previous step until you complete Table (I).

9) **Calculate** the value of ($\boldsymbol{g}$) for each height and **record** it in the appropriate column of your data table.

10) **Calculate** the average value ($\bar{g}$) and the standard error ($\sigma_{\bar{g}}$).

11) **Plot** the graph of height (h) versus (t^2) and determine the acceleration due to gravity from the slope.

Part B: Simple Pendulum

1) **Set up** the pendulum as in Figure 4, and **adjust** the length l to about 30 cm. The length of the simple pendulum is the distance from the point of suspension to the center of the ball.

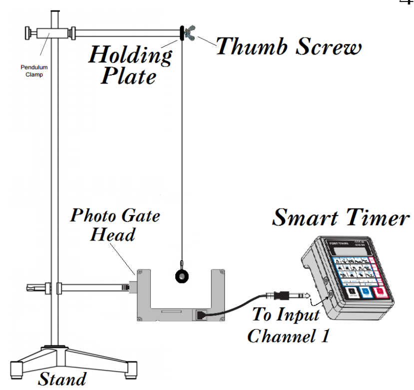

Figure 4. Simple Pendulum setup

2) **Adjust** the height of the photo-gate timer head in such a way that the beam passes through the center of the bob.

3) On the Smart Timer, **Press** the Red button #1 to select Time Measurement, and **press** the Blue button #2 to select "PENDULUM" Mode.

4) **Displace** the bob from its equilibrium position by a small angle and then release the bob to swing back and forth. While pendulum is swinging, **press** the Black button #3 on the Smart timer. The period T of the oscillation will automatically be displayed on the screen of the timer. **Record** the period T in Table (II).

5) **Repeat** the measurement of the period T one more time only by pressing the black Button #3 . **Calculate** the average value $\bar{T}$ of the periods and the squared $\bar{T}^2$ and **record** it in Table (II).

6) Increase the length of the pendulum by about 15 cm, and **repeat** the measurements made in the previous steps until the length increases to 110 cm.

7) **Calculate** the value of $\boldsymbol{g}$ for each length and **record** it in the appropriate column of your data table.

8) **Calculate** the average value $\bar{\boldsymbol{g}}$ and the standard error $\sigma_{\bar{g}}$.

9) **Plot** a graph of length l versus T^2 and **determine** the value of $\boldsymbol{g}$ from the slope.

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Partners: _

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Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Determination of Acceleration due to Gravity (g)

Objectives:

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Part A:

Table (I): Free Fall

h ( )*	t_1 ( )	t_2 ( )	$\bar{t}$ ( )	$(\bar{t})^2$ ( )	$\boldsymbol{g}$ ( )

Remarks:
*The units of the hight (h) should be converted from (cm) to (m)

Average value $\bar{g} =$ ....

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Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Determination of Acceleration due to Gravity (g)

Find the Standard Error:

g_i ( )					
(g_i-$\bar{g}$) ( )					
$(g_i$-$\bar{g})^2$ ( )					

Standard deviation (σg) = $\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(g_i - \bar{g})^2}$ = ...

Standard Error ($\sigma\bar{g}$) = $\frac{\sigma_g}{\sqrt{n}}$ = ...

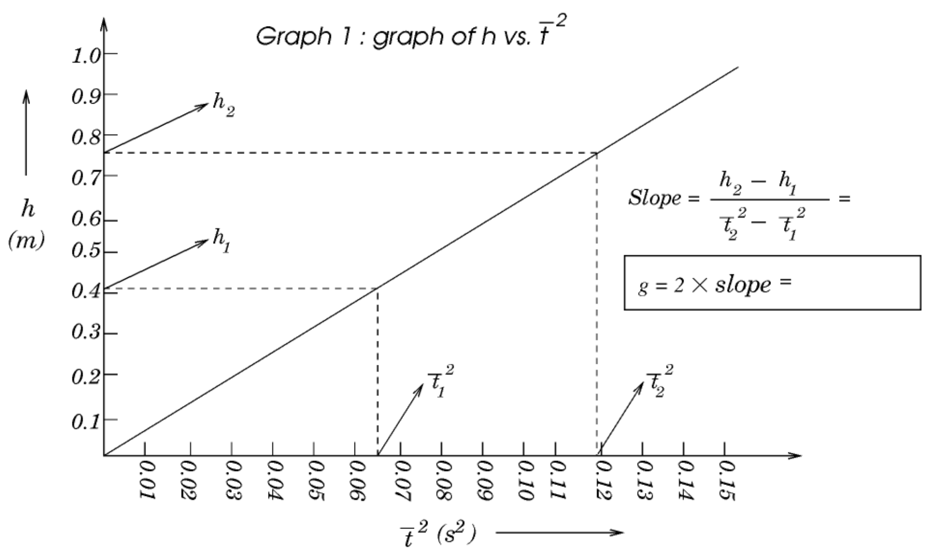
Result $\bar{g} \pm \sigma\bar{g}$ = ...

The value of (g_{graph}) = 2×slope = ...

Taking $(g_{theoretical} = 9.8\ \text{m/s}^2)$, the percentage error of your result is:

$\%\ Error = \left|\frac{g_{theoretical}-g_{graph}}{g_{theoretinal}}\right| \times 100 =$ ....

Plot the graph of h versus $\bar{t}^2$ and determine the value of g



- Drop both the small steel ball and the small wooden ball from the hight ($30cm$)and compare their time of flight: $t_{steel\ ball=}$.................... , $t_{wooden\ ball=}$....................

  Comment on your result: ....

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Determination of Acceleration due to Gravity (g)

Part B:

Table (II): Simple pendulum

l ( )*	T_1 ( )	T_2 ( )	$\bar{T}$ ( )	$(\bar{T})^2$ ( )	$\boldsymbol{g}$ ( )

Remarks:
*The units of the length (l) should be converted from (cm) to (m)

Average value $\bar{g}$ = ...

Find the Standard Error:

g_i ( )						
(g_i-$\bar{g}$) ( )						
$(g_i$-$\bar{g})^2$ ( )						

Standard deviation $(\sigma_g) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(g_i - \bar{g})^2}$ = ...

Standard Error $(\sigma_{\bar{g}}) = \frac{\sigma_g}{\sqrt{n}}$ = ...

Result $\bar{g} \pm \sigma_{\bar{g}}$ = ...

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

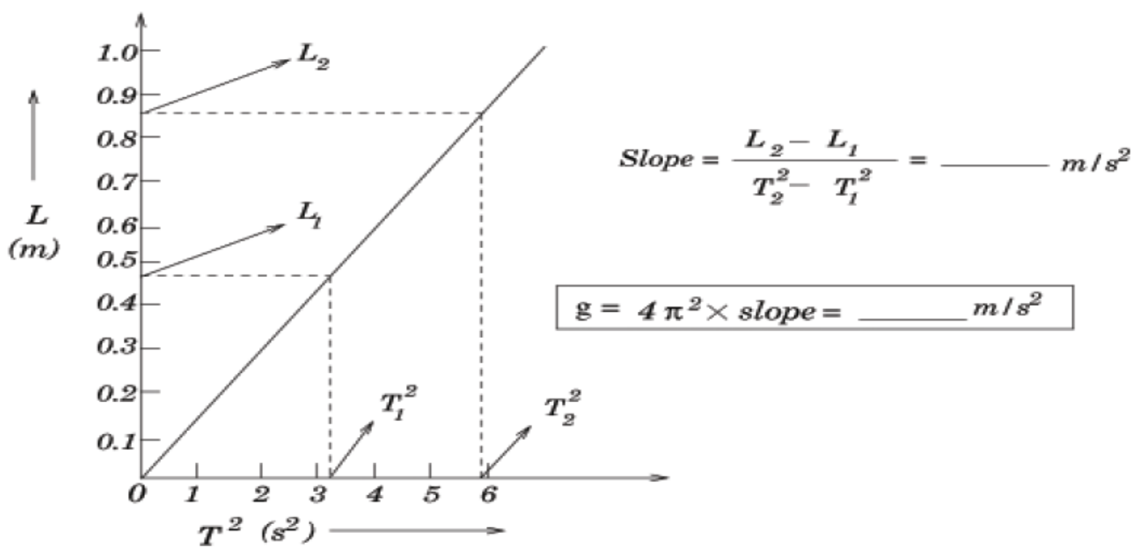
Determination of Acceleration due to Gravity (g)

The value of $\left(g_{graph}\right) = 4\pi^2 \times$slope = ...

Taking $\left(g_{theoretical} = 9.8 \text{ m/s}^2\right)$, the percentage error of your result is:

$$\%\ Error = \left|\frac{g_{theoretical} - g_{graph}}{g_{theoretinal}}\right| \times 100 = \text{................}$$

Plot the graph of l versus $\bar{T}^2$ and determine the value of g



- If the same experiment is performed on the moon ($g_{moon} = 1.6\ m/s^2$), what will be the value of the slope of l versus $\bar{T}^2$?..

- What will be the period of oscillation If the length of the simple pendulum is ($0.6\ m$)

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Physics Lab 105 *Student Number:*

Student Name: *Date:*

Determination of Acceleration due to Gravity (g)

Discussion and conclusion:

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Kuwait University Physics Department
Physics 105 & 125

Projectile Motion

Objectives

In this experiment we study the case in which the projectile is launched at an angle above the horizontal and onto the table top (floor) of a different level. The goal of this experiment is to determine how the horizontal distance traveled by this projectile depends on the launch angle, and determine the angle which gives the greatest horizontal distance for this projectile.

Equipment

- Projectile launcher mounted on stand.
- Two Smart Timers, with two accessory photogate heads.
- Time of flight accessory.
- Measuring tape.
- Plastic Ball.
- Carbon paper and white paper.

Theory

The projectile motion is a two-dimensional motion with constant acceleration. It can be analyzed as a combination of two independent motions. One motion along the x-direction where the accelerations $a_x = 0$ which makes it motion with constant velocity, and the other motion along the y-direction where the acceleration $a_y = -g$ which makes it motion with constant acceleration. To fulfill the goals of this experiment, we study the projectile motion in both directions. Along the x-axis, the horizontal distance, x, between the muzzle of the Launcher and the place where the projectile lands on a surface, is given by:

$$x = v_x t = (v_o \, cos \, \theta) t \tag{1}$$

where v_o is the initial speed of the projectile as it leaves the muzzle, θ is the launch angle above horizontal, and t is the time of flight.

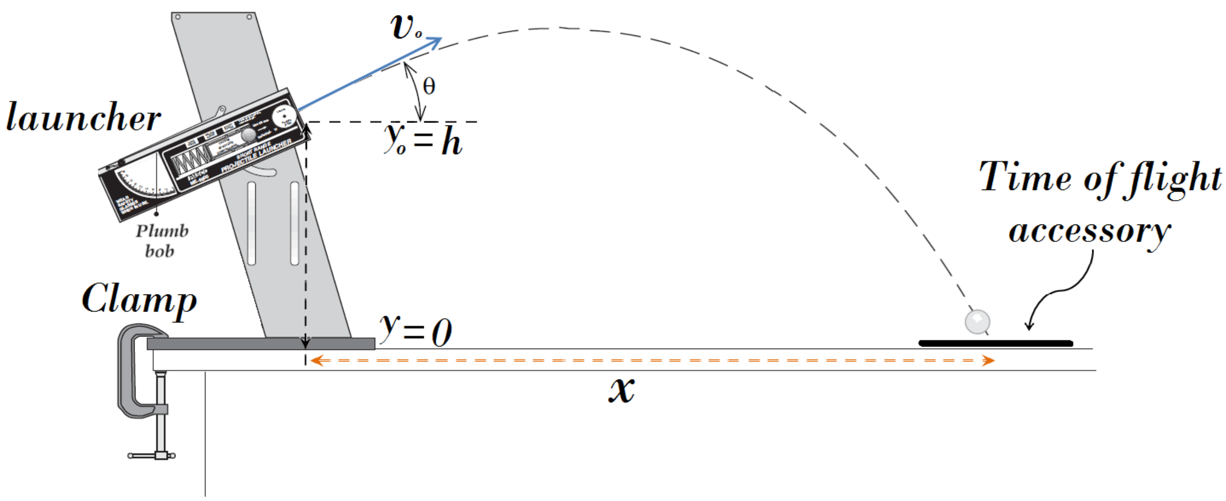

Figure 1. Experimental setup for Projectile motion.

Therefore, for each shooting angle, we compare the measured and the calculated horizontal distance x of the projectile. Along the y-direction ;however, the vertical displacement (Δy) of the projectile equals:

$$\Delta y = v_{o_y} t + \frac{1}{2}(a_y)t^2 = (v_o \, sin \, \theta)t - \frac{1}{2} g t^2 \tag{2}$$

where v_o is the initial speed of the projectile as it leaves the muzzle, θ is the launch angle above horizontal, and t is the time of flight.

Procedure

1) **Choose** one corner of the working table to place the projectile launcher. Make sure a distance of about 3 meters is clear on the table.

2) **Clamp** the stand of the launcher to the corner of the working table using the Universal "**C**" Clamp (see Figure 1. above).

3) **Slide** the Photogate Bracket into the **T**-slot on the bottom of the launcher and **tighten** the thumb screws underneath to fix the two photogates to the bracket (Figure 2 below).

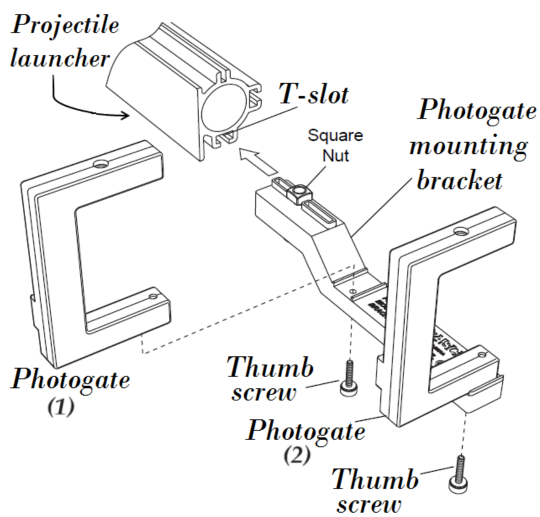

Figure 2. Installing Photogate bracket.

4) Using the attached plumb bob, **adjust** the angle of the launcher to 20^o and **tighten** the thumb screws behind the stand to secure the inclination angle.

5) Out of photogate head No.1 (the one closer to the launcher muzzle), there are two output wires. **Plug** one output wire into port-1 of the first Smart Timer-(1), and **Plug** the other output wire into port-1 of the second Smart Timer-(2). (See Figure 3).

6) **Plug** the output wire of the second photogate head No.2 (the one further away from the launcher muzzle), into port-2 on the first Smart Timer-(1) . Also,

Plug the output wire of the time of flight accessory into port-2 on the second Smart Timer-(2). (See Figure 3).

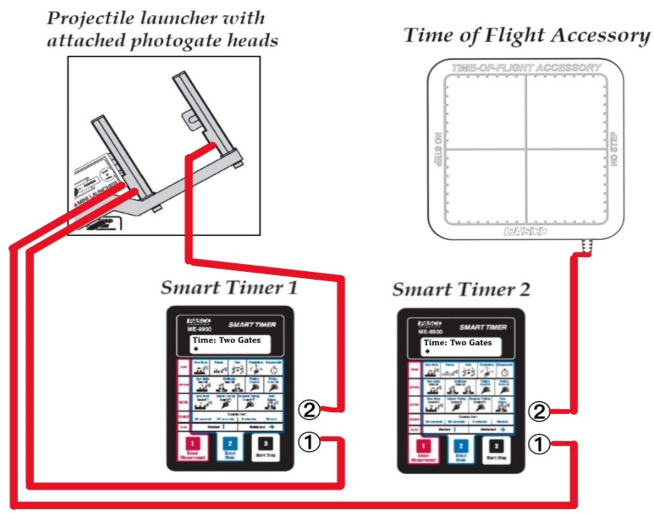

Figure 3. Circuit connection of both Smart Timers and Photogate heads.

7) **Put** a plastic ball in the Projectile Launcher and use the plastic rod to cock it to the middle range position.

8) **Turn on** both Smart Timers. Using the red"Select Measurement" button, **choose** the "Time" measurement. Using the blue "Select Mode" button, **choose** the "Two Gates" Mode.

9) As a first trial, **shoot** the ball and determine where about it will land on the working table top (floor). **Position** the Time of Flight accessory at the landing sight.

10) **Use** a single sheet of white paper and carbon paper to cover the Time of Flight Accessory.

11) Using the plastic rod, cock the Projectile Launcher with a ball to the middle range position once again, **press** the black "Start/Stop" button on both Smart Timers. Make sure you hear a small tiny "BEEB" sound and you see a small (∗)

on the screen of both timers. **Shoot** the ball and allow it to land on the carbon paper. On Smart Timer-(1), **read** the time (Δt) it takes the projectile to travel a distance of 0.1m between the two photogates. **Calculate** the initial velocity (v_o)of the ball and **record** it the table below. Also, from Smart Timer-(2) **read** the total time of flight (t) it takes the projectile to reach the Time of Flight Accessory. **Record** it in the data Table below.

12) **Use** the measuring tape to measure the horizontal distance (x_{meas}) of the projectile. This distance has to be measured from the "*Orange Mark*" on the base of the Launching Stand to the black dot the carbon paper produces on the white paper on top of the Time of Flight accessory. **Record** the data in Data Table below.

13) As illustrated in Equation 1, **Use** the initial velocity and the angle to **Compute** the calculated horizontal distance (x_{calc}) in meters.

14) **Compare** your result of the calculated and measured horizontal distance.

15) **Plot** the relation between the calculated range versus the angle. This graph you will draw looks like a smooth curve through the points.

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Physics Department

Date: [ ] [ ] [ ]
day month year

Experiment ( ): ______________________________

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*Student name:*______________________ *Student number:*___________

Instructor name: _______________________

Partners: __________________________

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Total Mark

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Projectile Motion

Objectives:

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Table I.

θ (deg)	Δt ( )	$v_o = \frac{0.1m}{\Delta t}$ ( )	t ( )	x_{meas} ( )	$x_{calc} = (v_o cos\,\theta)\ t$ ( )
20					
25					
30					
35					
40					
45					
50					
55					
60					
65					
70					

∗ From the graph, what angle gives the maximum horizontal displacement?

....

∗ Comment on the acceleration of motion in the x-direction and in the y-direction:

....

∗ What is the speed of the projectile at the top of the trajectory?

....

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Physics Lab 105 & 125

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Student Name:

Date:

Projectile Motion

∗ Using equation (2) and you data from Table I, **Calculate** the vertical displacement (Δy) for the following angle:

for $\theta = 30^o$...

for $\theta = 50^o$...

∗ Is the vertical displacement (Δy) positive or negative? Explain.

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Discussion and conclusion:

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Physics 105 & 125

Static Equilibrium of forces and Hook's Law

Objectives

The aim of this experiment is to study the "**Static equilibrium of forces**" and develop the conditions required to maintain equilibrium for a system of objects. (Newton's 2^{nd} and 3^{rd} Laws). We also study Hook's law and employ the theory of Static equilibrium of forces to calibrate a spring as a dynamometer and use it for the measurement of forces. We finally, use the theory of Static equilibrium once again to decompose forces into perpendicular components.

Equipments:

- Experimental board with mass hangers (mass 5 g),
- Mass pieces (10 g,20 g, 50 g, 100 g),
- Dynamometer (spring balance with three different scales).
- Force Table Assembly with Legs.
- Super Pulley with Clamp

Theory

In this experiment the method of decomposing a force into components and expressing a force as a Cartesian vector will be used to solve problems involving equilibrium of particles. A particle of mass m under the influence of n number of forces is said to be in equilibrium provided it is at rest if originally at rest, or has a constant velocity if originally in motion. In both cases, the acceleration of the particle equals zero. Therefore, to maintain the state of equilibrium:

$$\sum_{i=1}^{n} F = m\,a = 0 \tag{1}$$

Since forces are vectors, and since we will mainly be dealing with forces that act in the xy plane, then Equation 1 states that the components of the net force must each be zero. Thus, the condition for equilibrium is written as:

$$\sum_{i=1}^{n} F_x = 0, \quad \sum_{i=1}^{n} F_y = 0. \tag{2}$$

Hook's Law

Suppose you are holding a simple coil spring of natural (or unstretched) length L. When you apply a force F_x to stretch the spring and cause an (x) amount of extention beyond its natural length, the force F_x is found to be directly proportional to the extension (x). See Figure 1.

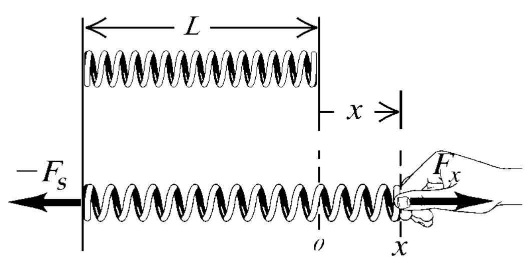

Figure 1. A spring of natural length x with applied force F_x.

Therefore, the force F_x can be written as

$$F_x = k\,(x).$$

Where k is a constant, known an the *Spring constant* or *Force constant*. It represents a measure of how elastic or how stiff this particular spring is. The extention in length (x), on the other hand, should be small because the elasticity feature of the spring may be damaged if you extend the spring beyond its elastic limit. The spring itself is found to exert a force F_s to the opposite direction of the applied force F_x. This force is known as restoring force because it tends to restore the spring to its natural length, and is given by **Hook's Law**:

$$F_s = -k\,(x). \tag{3}$$

In order to calculate the spring constant k of the Dynamometer in the lab, we apply a force of a known magnitude F_w, (that is equal to the weight of a known mass m. See Figure 2), and measure the resulting extension to the spring.

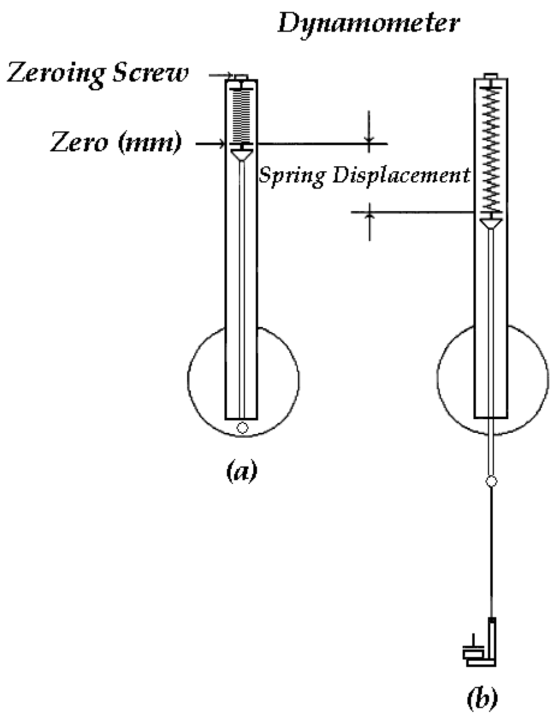

Figure 2. (a) The Dynamometer with its natural length
(b) The Dynamometer with applied force F_w.

Since the acceleration of the hanging mass equals zero; The forces acting on it are said to be in equilibrium. Therefore, we can write

$$\rightharpoonup F_w + F_s = 0 \Longrightarrow mg - k(y) = 0 \Longrightarrow k = \left(\frac{mg}{y}\right) \tag{4}$$

Notes that the extention of spring length is denoted by (y).

Decomposition of Forces

In this part of the experiment we test the validity of the conditions necessary for static equilibrium of forces, which are stated previously in Equation 2. Suppose we have three forces acting on a circular object that is either at rest or moving with constant velocity. See Figure 3.

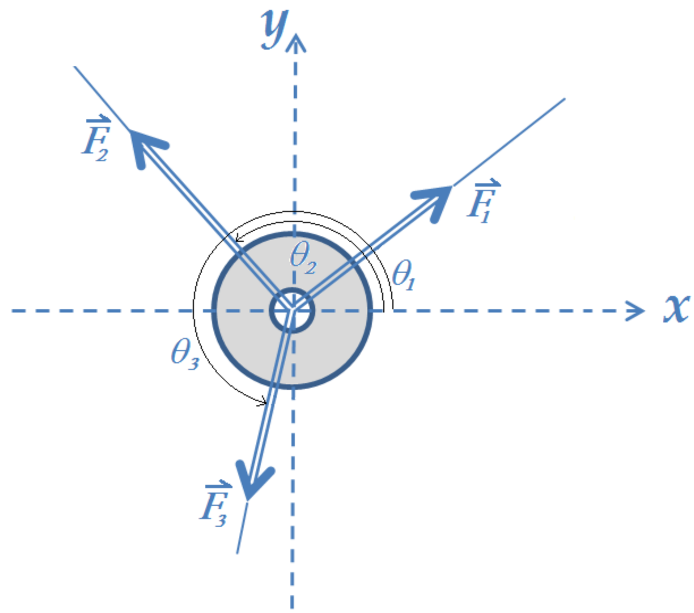

Figure 3. Free-Body Diagram

If the object is at rest, then:

- along the x-direction, we should have:

$$F_{1_x} + F_{2_x} + F_{3_x} = 0 \Longrightarrow F_1\, cos\, \theta_1 + F_2\, cos\, \theta_2 + F_3\, cos\, \theta_3 = 0$$

- along the y-direction we should have:

$$F_{1_y} + F_{2_y} + F_{3_y} = 0 \Longrightarrow F_1\, sin\, \theta_1 + F_2\, sin\, \theta_2 + F_3\, sin\, \theta_3 = 0$$

Refer to Figure 4. The exact same analysis is carried out to show that the x component of the force F_3 that is provided by the mass m_3 and applied to the force ring, is in fact equal in magnitude to the sum of the x components of the forces F_1 and F_2 applied to the same force ring by the hanging masses m_1 and m_2. Similarly, along the y direction, we should show that the magnitude of the force F_3 applied to the force ring by the hanging mass m_3 is equal to the sum of the magnitude of the y components of the remaining forces F_1 and F_2.

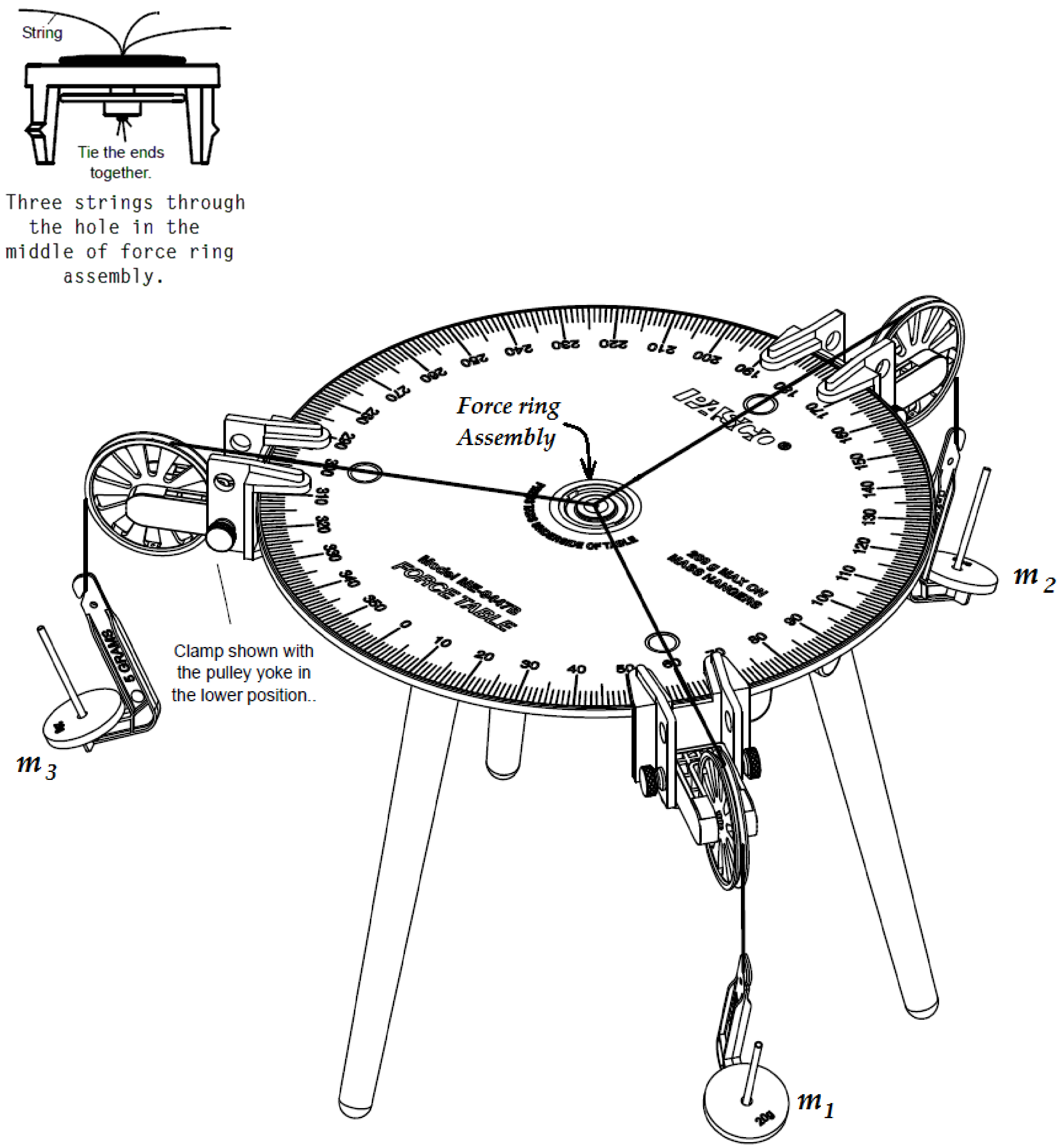

Figure 4. Assemble the force table as shown. Use three super pulley clamps (two for the forces that will be added and one for the force that balances the sum of the other two forces). Arrange the strings from the Force Ring over the pulleys.

Procedure

Part I: Hook's Law

1) **Hang** the spring balance on the experimental board (Figure 2.). Be sure the spring hangs vertically in the plastic tube.

2) With no force applied to the spring balance, **adjust** the zeroing screw on the top of the spring balance until the indicator is aligned with the $0\,mm$ mark on the millimeter scale of the spring balance as shown in Figure 2(a).

3) **Hang** the $5\,gram$ mass hanger with a $50\,gram$ mass from the spring balance.

4) **Measure** the spring displacement (y) on the millimeter scale as shown in Figure 2(b). **Record** the values of the total mass (m_{total}) and the spring displacement (y) in Table (I).

5) **Repeat** step 4 with other total masses according to Table (I).

6) **Calculate** the total weight in newton for each value of the total mass (m_{total}). **Record** your results in the table.

7) **Calculate** the spring constant k using Equation (4).

8) **Plot** the applied force $F_w = m_{total}g$ versus spring displacement (y). The slope of the graph is the spring constant k for the spring used in the dynamometer.

Part II: Force Decomposition

1) **Set up** the equipment with force table, mass hanger, masses, super pulleys, force ring assembly and string as shown in Figure 4.

2) **Hang** the mass hangers directly to the strings attached to the force ring assembly. **Adjust** the strings from the Force ring assembly over the Super Pulleys.

3) **Apply** two forces F_1 and F_2 on the force table by handing masses m_1 and m_2 over pulleys position at certain angles as indicated in Table (II) below.

4) **Adjust** the angle θ_3 and amount of mass m_3 hanging over the third pulley until the force F_3 from this pulley balances the forces F_1 and F_2 from the other two pulleys

5) **Test** whether the system is in equilibrium. The clear disk on the Force Ring assembly must be centered when the system is in equilibrium. **Pull** the disk slightly to one side and let it go. **Check** to see that the disk returns to the center in the Force Ring assembly. If not, **adjust** the mass m_3 and/or the angle θ_3 of the super pulley clamp until the disk always returns to the center when pulled slightly to one side.

6) **Verify** the conditions of static equilibrium along the X and Y directions.

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Experiment ( ): ______________________________

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*Student name:*______________________ *Student number:*___________

Instructor name: _______________________

Partners: __________________________

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Total Mark

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Static Equilibrium of forces and Hook's Law

Objectives:

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Part I. Hook's Law

Table I. Determination of Spring force constant k.

M_{total} (g)	y ( )*	$F_w = m_{total}g$ ( )**	$k = \frac{F_w}{y}$ ( )
95			
115			
135			
175			
195			
225			

Remarks: $*$ Spring extension (y) should be converted from (mm) to (m).

$**$ The measurements of (m_{total}) should be converted from (g) to (kg).

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Static Equilibrium of forces and Hook's Law

Standard deviation and standard error calculation:
Find the average value of spring force constant k of the dynamometer i.e,

$$\overline{k} = \frac{k_1 + k_2 + k_3 + k_4 + k_5 + k_6}{6} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Complete the following table and report the result in the form $\bar{k} \pm \sigma_{\bar{k}}$.

quantity	k_1	k_2	k_3	k_4	k_5	k_6
k_i						
(k_i - $\overline{k}$)						
(k_i - $\overline{k}$)^2						

standard deviation:

$$\sigma_k = \sqrt{\frac{1}{n-1}\sum_{i=1}^{i=n}(k_i - \overline{k})^2} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

standard error($\sigma_{\overline{k}}$).

$$\sigma_{\overline{k}} = \frac{\sigma_k}{\sqrt{n}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

RESULT : $\bar{k} \pm \sigma_{\bar{k}}$= ....

Determine the percentage error of k obtained ($k_{theory} = 50N/m$):

$$\left|\frac{k_{theory} - k_{calculated}}{k_{theory}}\right| \times 100 = \frac{\ldots\ldots\ldots - \ldots\ldots\ldots}{\ldots\ldots\ldots} \times 100 = \ldots\ldots\ldots\ldots\%$$

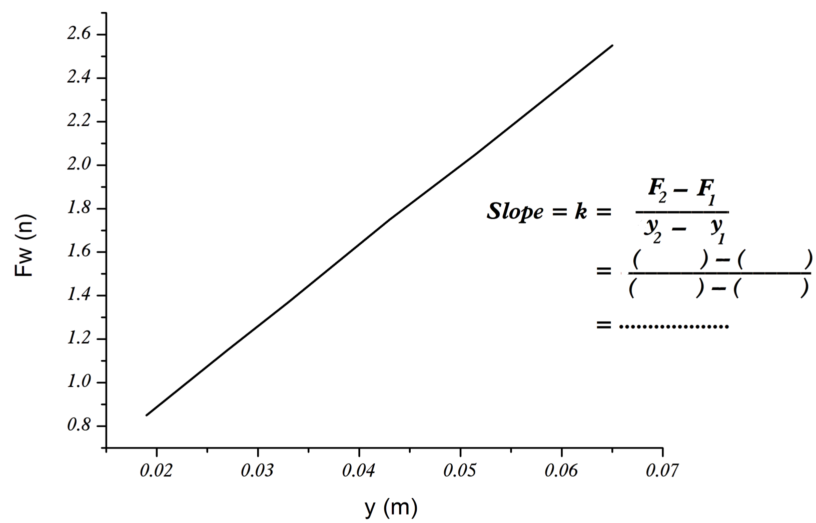
Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Static Equilibrium of forces and Hook's Law

Plot a graph of F_w versus y and determine the spring force constant (k)



Part II. Forces Decomposition

Hang the following masses over two of the super pulleys and clamp the pulleys at the given angles.

Table II.

Masses (g)	$F = mg$ ( )	Angles Deg
$m_1 = 205g$	$F_1 =$	$\theta_1 = 30^o$
$m_2 =$ g	$F_2 =$	$\theta_2 =$
$m_3 = 225g$	$F_3 =$	$\theta_3 = 261^o$

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Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Static Equilibrium of forces and Hook's Law

Calculate the x and y components for each force acting on the Force Ring:

F_{1_x} = ... F_{1_y} = ...

F_{2_x} = ... F_{2_y} = ...

F_{3_x} = ... F_{3_y} = ...

From your result, test whether forces are in equilibrium the x direction?

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From your result, test whether forces are in equilibrium the y direction?

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Discussion and conclusion:

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Physics 105 & 125

Conservation of Mechanical Energy

Objectives

The goal of this experiment is to set a Mini-car in motion from rest on a step downhill like track and investigate the conservation of mechanical energy of this car at various points along the track which includes a circular loop configuration as well as a straight flat portion. The height from which the car must be released from rest on the down-hill step so that it can just barely make it through the loop can be predicted from conservation of energy and the centripetal acceleration. Furthermore, calculation of the normal force acting on the car at the top of the circular loop is carried out.

Equipments:

- Roller Coaster Complete System.
- Measuring devices: Metric Ruler.
- Photogate heads connected to Smart Timer.

Theory

Mechanical energy is E is defined as the sum of both Kinetic energy K and the Potential energy U of all objects or particles in a given isolated physical system.

$$E = K + U$$

Conservation of mechanical energy requires that the mechanical energy of any isolated system remains constant in time, which means that total amount of mechanical energy of the moving particles of the system is not subject of any changes as long as the system is isolated and free of all frictional and other non-conservative forces. A decrease or increase in the kinetic energy of the system is accompanied by an equal increase or decrease in its potential energy. Thus kinetic and potential energies are transformed into each other during the motion of the particles of the system in such a way that the mechanical energy remains unchanged.

The expression of conservation of mechanical energy at any point on the roller coaster track can be written simply as:

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f \tag{1}$$

Where i and f both represent the initial and final state of the moving particles. In the presence of Non-conservative forces such as friction, initial and final mechanical energy will not be the same which leads to the fact that

$$\Delta E = E_f - E_i = W_{friction}$$

In this experiment (Figure 1), a single particle (Mini-car) is released from rest on the top of the hill at point (A), reaches the bottom of the hill at point (B), it then goes through a single vertical circular loop (B) and to a straight segment from (D) till it reaches point (E).

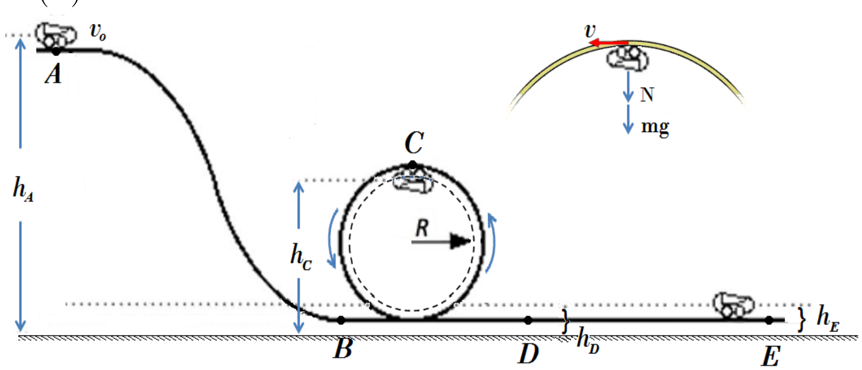


Figure 1. Experimental Setup.

The Normal force (n) acting on the Mini-car at the top of the circular loop (C) is calculated from Newton's second law along the y-direction:

$$\sum F_y = m\,a_c$$

Where (F_y) represent the sum of all y components of the existing forces acting on the car, and (a_c) is the centripetal acceleration of the moving car in a uniform circular motion. Therefore;

$$n + mg = m\frac{v^2}{R}$$

$$n = m\left(\frac{v^2}{R} - g\right) \tag{2}$$

Procedure

1) **Configure** the track as shown in Figure 2. The photogate heads should be attached to the bottom of the hill (point B), the top of the loop (point C), and to the straight portion of the track at (point D) and (point E).

2) **Put** the catcher at the end of the straight part of the track to keep the car from going off the end of the track.

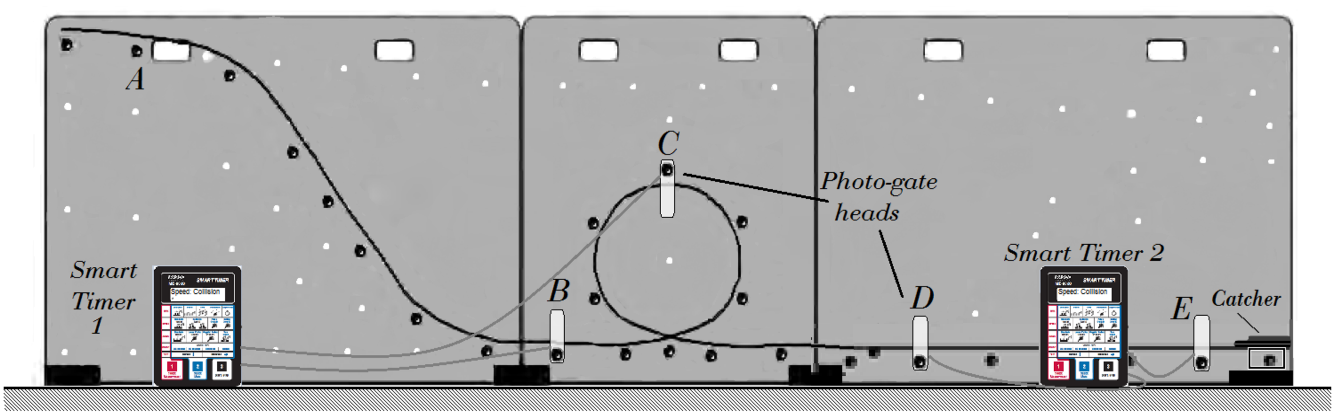


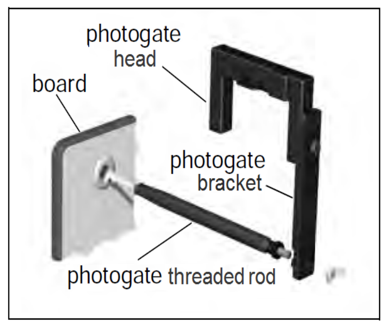
Figure 2. Experimental Board with Loop setup and photogate heads attached.

3) **Place** the Mini-car at the top of the step on the left (Point A). **Mark** on the white board where you release the car. **Measure** the initial height (h_A) of the car from the table to the center of mass of the car. Note that the center of mass of the car is approximately at the slot where the flag is inserted.

4) **Place** the Mini-car at the top of the loop from the inside (Point C). **Hold** the car with one hand and **Mark** on the position of the center of mass of the car on the white board. **Measure** the radius (R) of the loop and the distance (h_C) from the center of mass of the car at the top of the loop to the table.

5) **Place** the car at the bottom on the flat part of the track (Point D) and **measure** the height (h_D) of the car from the table and **repeat** the measurement at (Point E) in order to measure (h_E).

6) **Attach** the photogate head to the photogate bracket, and **use** the wing nut to attach the bracket onto the photogate threaded rod. at points (B), (C), (D) and (E) along the track.(Figure 2).



7) On Smart Timer-1, **Connect** the jack of photogate (B) to the input channel 1. Also, **Connect** the jack of photogate (C) to the input channel 2.

8) On Smart Timer-2, **Connect** the jack of photogate (D) to the input channel 1. Also, **Connect** the jack of photogate (E) to the input channel 2.

9) On the touch pad keys of both smart timers:

   * **Press** the `Select Measurement` (# 1 RED) key until you read “SPEED” the top line of the display.

   * **Press** the `Select Mode` (# 2 BLUE) key until you read “COLLISION” the top line of the display.

* In order to measure the velocity of the moving Mini-car at points (B), (C) (D) and (E), **Press** the `Start/Stop` (# 3 BLACK) key then **release** the car from the top of the step hill on the left (Point A). When the car reaches the catcher, **Press** the `Start/Stop` (# 3 BLACK) key once again to stop the timer. The displayed result of the velocity at point (B) and (C) on Smart Timer-1 and the velocity at point (D) and (E) on Smart Timer-2 respectively are of the following format:

1: XX.X , 00.0 (cm/s) ← [press (#1) or (#2)] → **2: YY.Y , 00.0** (cm/s)

10) On the data sheet, **record** the results of velocities on the left side of the data Table, and **calculate** the total mechanical energy at of the moving car.

11) **Repeat** this entire experiment but with additional mass piece added to the Mini-car. **Record** your readings on the right side of the data Table.

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Date: [ ] [ ] [ ]
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Student Serial Number:

Experiment (   ): _

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Student name:_ Student number:_ _ _ _ _ _ _ _ _ _ _

Instructor name: _

Partners: _

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Student Number:

Student Name:

Date:

Conservation of Mechanical Energy

Objectives:

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Table (I): Conservation of Mechanical Energy

$R =$ ......( )**	$m_{car} =$ ....( )*					$m_{car} + m_{steel} =$ ....( )*				
	Point A	Point B	Point C	Point D	Point E	Point A	Point B	Point C	Point D	Point E
height (h) ( )**	$h_A =$	$h_B =$	$h_C =$	$h_D =$	$h_E =$	$h_A =$	$h_B =$	$h_C =$	$h_D =$	$h_E =$
velocity (v) ( )***	$v_A =$	$v_B =$	$v_C =$	$v_D =$	$v_E =$	$v_A =$	$v_B =$	$v_C =$	$v_D =$	$v_E =$
P. Energy (U) ( )	$U_A =$	$U_B =$		$U_D =$	$U_E =$	$U_A =$	$U_B =$		$U_D =$	$U_E =$
K. Energy (K) ( )	$K_A =$	$K_B =$		$K_D =$	$K_E =$	$K_A =$	$K_B =$		$K_D =$	$K_E =$
Mechanical Energy (E) ( )	$E_A =$	$E_B =$		$E_D =$	$E_E =$	$E_A =$	$E_B =$		$E_D =$	$E_E =$
Percentage of Total energy lost	$= \left\|\frac{E_A - E_B}{E_A}\right\| \times 100$			$= \left\|\frac{E_D - E_E}{E_D}\right\| \times 100$		$= \left\|\frac{E_A - E_B}{E_A}\right\| \times 100$			$= \left\|\frac{E_D - E_E}{E_D}\right\| \times 100$	

Remarks: $*$ The units of mesurements of mass should be converted from (g) to (kg).

$**$ The units of measurements of height should be converted from (cm) to (m).

$***$ The units measurements of velocity should be converted from (cm/s) to (m/s).

Kuwait University **Physics Department**

Physics Lab 105 & 125

Student Number:

Student Name:

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Conservation of Mechanical Energy

Questions:

The following questions are related to the part of the experiment when the Mini-car **Only** was used:

1 - Calculate the amount of work done by friction on the car as it travels from point (**A**) to (**B**), and from point (**A**) to (**E**).

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2 - Compare your results for question 1 and state which trip has larger friction and why?

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3 - Calculate the normal force acting on the Mini-car as it passes through the top of the circular loop at point (**C**) from the inside.

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Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Conservation of Mechanical Energy

4 - What is the speed (v_C) of the car at point (**C**) in order to have zero normal force acting on it at this point?

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5 - What should be the minimum height (h_A) of the car at point A in order for it to have zero normal force when it reaches the top of the circular loop at point (**C**)?

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6 - Compute the normal force acting on the car at point at point (**B**).

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7 - Compute the centripetal acceleration (a_c) of the car as it moves in a uniform circular motion in the loop at point (**C**).

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Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Conservation of Mechanical Energy

Questions:

The following questions are related to the part of the experiment when the Mini-car and 50g mass piece were used:

1- How does increasing the mass of the car change the total mechanical energy at points (**A**) and (**B**)?

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2- How does increasing the mass of the car change the speed of the car at points (**B**) and (**C**)?

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Physics Lab 105 & 125 *Student Number:*

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Conservation of Mechanical Energy

Discussion and Conclusion:

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Physics 105 & 125

Explosion and Elastic Collision

Objectives

The objective of this experiment is to study the conservation of linear momentum, conservation of kinetic energy, and to demonstrate both conservation laws for a one-dimensional elastic head-on collision as well as explosion.

Equipment

- 1.2 m long track with Feet and End stops.
- frictionless Plunger cart,
- frictionless Collision Cart,
- 250g (short) and 500g (long) Black Mass Bars,
- Smart timer with 2 accessory photogates.
- Photo-gate timer with accessory photo-gate.

Theory

The linear momentum $\vec{p}$ and the kinetic energy K of an object of mass m moving with velocity $\vec{v}$ is defined as

$$\vec{p} = m\vec{v} \quad , \quad K = \frac{1}{2}mv^2 \tag{1}$$

Collisions usually are categorized into two major types, mainly "Elastic collision" or "Inelastic collision". The Inelastic collision is divided further into two main subcategories known as the "Partial inelastic collision", where the lose of kinetic energy can be greater that zero and less than 100%. The second type; however, is known as the "Total Inelastic collision" where the lose of kinetic energy will be exactly equal to 100%. One has to keep in mind that for all types of collisions mentioned above, that linear momentum is conserved.

When two bodies with masses m_1 and m_2 moving along the x-axis with initial velocities $\vec{v}_{1_i}$ and $\vec{v}_{2_i}$ encounter an elastic head-on collision, the total linear momentum will be conserved, i.e.:

$$\vec{p}_{1_i} + \vec{p}_{2_i} = \vec{p}_{1_f} + \vec{p}_{2_f}, \tag{2}$$

or

$$m_1\vec{v}_{1_i} + m_2\vec{v}_{2_i} = m_1\vec{v}_{1_f} + m_2\vec{v}_{2_f}. \tag{3}$$

And the total kinetic energy of the system is conserved as well. i.e.:

$$K_{1_i} + K_{2_i} = K_{1_f} + K_{2_f}. \tag{4}$$

or

$$\frac{1}{2}m_1 v_{1_i}^2 + \frac{1}{2}m_2 v_{2_i}^2 = \frac{1}{2}m_1 v_{1_f}^2 + \frac{1}{2}m_2 v_{2_f}^2. \tag{5}$$

And this type of collision is referred to as Elastic collision.

As an example of completely inelastic collision we should analyze the case of explosion. In this experiment, we will consider the case when the physical system is divided, due to the explosion, to two product bodies pushed away from each other. If the system is initially at rest, then both the total initial linear momentum and the total initial kinetic energy of the physical system are equal to zero. Consequently, the linear momentum of both bodies after the explosion will be equal in magnitude and opposite in direction. i.e.:

$$\vec{p}_{1_f} = -\vec{p}_{2_f} \Longrightarrow |\vec{p}_{1_f}| = |\vec{p}_{2_f}|$$

The kinetic energy, however is not conserved. Although the initial kinetic energy of both bodied is zero, their final kinetic energies are related as follows:

$$K_{1_f} = K_{2_f} \left(\frac{m_2}{m_1}\right)$$

Procedure

Conservation of Momentum in Explosions

1) **Mount** an end stop at each end of the track and **Level** the track by adjusting the two screws beneath the Feets on both sides of the track until a glider placed at the center of track becomes stationary.

2) **Put** two photogates on the mounting brackets or stand. They should be positioned near the center of the track. as shown below.

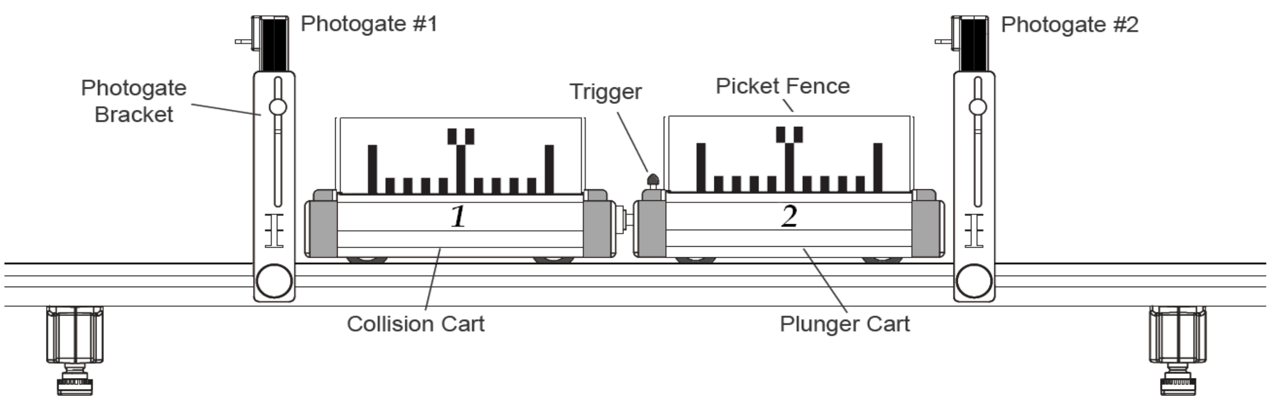

Figure 1. Experimental setup for One Dimensional Explosion.

3) **Put** a picket fence into the slots on top of each cart. **Label** one cart as "cart 1" and the other (the cart with plunger) as "cart 2".

4) **Measure** the total mass of each cart with its picket fence and **record** the values in kilograms in the data Table (I).

5) **Adjust** the hight of the both photogates so that the beam can read the full width of the two black strips at the top of the picket fences that are attached to the carts. **Connect** both the photogates to Channel 1 & 2 on the smart timer. The photogates must be positioned such that they are near the end of each cart (see Figure 1).

6) **Push** in the plunger of the plunger cart (cart 2) to its third notch. **Put** the carts end-to-end in the middle of the track.

7) **Set up** the Smart Timer to measure Speed by pressing button #1 on timer key pad, and select **collision (cm/s)** mode by pressing button #2 on timer key pad of the Smart Timer

8) **Start** the Smart Timer by pressing button #3 on timer key pad. You should be able to see the symbol (*) on the display of the Smart timer. **Tap** the plunger release button (trigger) with a short stick to set both carts in explosion motion.

9) **Record** your measurements of the velocity in the first line (trial 1) of Table (I) below. Note that the smart timer measures speed only (which is always positive or zero) however the velocity recorded in Table (I) must include the signe (pluse or minus) according to the direction of motion of the cart.

10) For the second trial, **put** a 250 g mass bar into "cart 2" only. (Do not add any mass bars to the other "cart 2").

11) For the third trial, **put** 250 g of extra mass into the "cart 2". **Measure** and **record** the new mass of the cart, and **repeat** the data recording procedure.

Conservation of Momentum in Elastic Collisions

1) **Set up** the carts so the magnetic ends face each other by rotating "cart 2" 180^o horizontally, so the carts will repel each other by magnetic force when they collide.

2) **Place** "cart 2" at rest in the middle of the track (The collision zone) and "cart 1" should be kept at the left end of the track (See Figure 2).

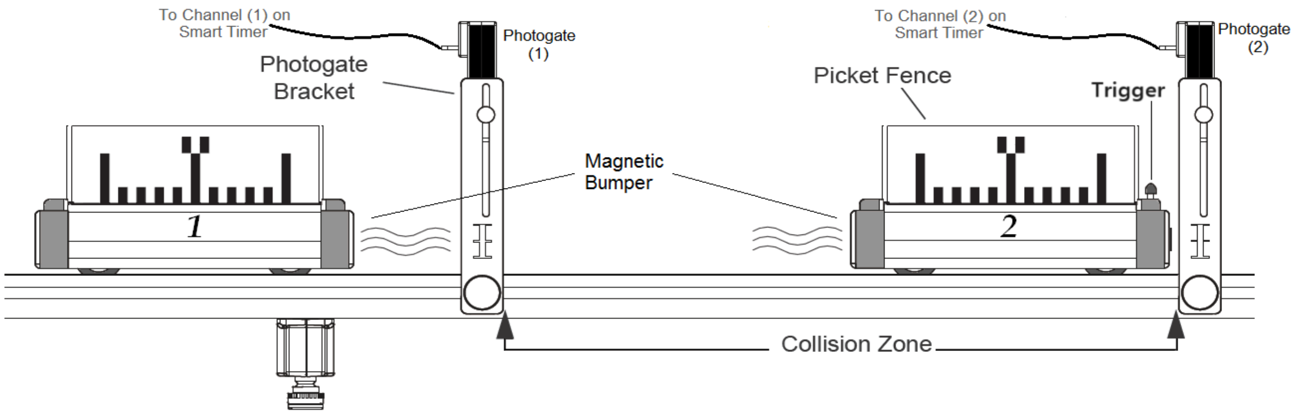

Figure 2. Experimental setup for One Dimensional Elastic Collision.

3) **Set up** the Smart Timer to measure Speed by pressing button #1 on timer key pad, and select **collision (cm/s)** mode by pressing button #2 on timer key pad of the Smart Timer.

4) **Start** the Smart Timer by pressing button #3 on timer key pad. You should be able to see the symbol (*) on the display of the Smart timer.

5) **Give** "cart 1" an initial velocity by pushing it gently with your hand toward the "cart 2" which is at rest. **Weigh** the carts and **record** the masses and the velocities in Table (II) including the signe of the velocity (pluse or minus) according to the direction of motion of the carts.

6) **Repeat** the previous step; however, **Put** the 500g mass bar into "cart 2" and **Place** it at rest in collision zone in the middle of the track. **Give** "cart 1" an initial velocity toward "cart 2". **Weigh** the carts and **record** the masses and velocities in Table (II).

7) For the third trial, **put** 250 g extra mass into the "cart 2". **Record** the new mass of both carts in Table (II), and **repeat** the data recording procedure.

Kuwait University

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Course / Section:_ _ _ _ _ _ _ _ _

Date: day month year

Student Serial Number:

Experiment ( ): _

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Student name:_ _

Student number:_ _ _ _ _ _ _ _ _ _ _

Instructor name: _

Partners: _

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Total Mark

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Explosion and Elastic Collision

Objectives:

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Conservation of Momentum in Explosions

Table 1: M_{cart_1} = ...( )* , M_{cart_2} = ...( )*

Trial	M_1 ( )*	M_2 ( )*	v_{1_f} ( )**	v_{2_f} ( )**	$p_{T_i} = M_1 v_{1_i} + M_2 v_{2_i}$ ( )	$p_{T_f} = M_1 v_{1_f} + M_2 v_{2_f}$ ( )	% Error= $\left\| \frac{\|P_{T_i}\| - \|P_{T_f}\|}{\|P_{T_i}\| + \|P_{T_f}\|} \right\| \times 100$
Trial 1 cart 1↦Empty cart 2↦Empty							
Trial 2 cart 1↦Empty cart 2↦+250g							
Trial 3 cart 1↦Empty cart 2↦+500g							

Remarks: $*$ The units of mesurements of mass should be converted from (g) to (kg).

$**$ The units measurements of velocity should be converted from (cm/s) to (m/s).

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Explosion and Elastic Collision

Measurements:

Trial 1:

$K_{total_i} = K_{1_i} + K_{2_i} =$ .... , $K_{total_f} = \frac{1}{2}M_1 v_{1_f}^2 + \frac{1}{2}M_2 v_{2_f}^2 =$ ....

Trial 2:

$K_{total_i} =$ .... , $K_{total_f} = \frac{1}{2}M_1 v_{1_f}^2 + \frac{1}{2}M_2 v_{2_f}^2 =$ ....

Trial 3:

$K_{total_i} =$ .... , $K_{total_f} = \frac{1}{2}M_1 v_{1_f}^2 + \frac{1}{2}M_2 v_{2_f}^2 =$ ....

- For any given Trial. Check whether linear momentum is conserved?

  ....

- For any given Trial. Check whether kinatic energy is conserved?

  ....

- Based on the results obtained in Table 1, Please compare the velocity (magnitude and direction) of both carts after the explosion and write a brief comment to explain which cart has the larger velocity?, and why?

In Trial (1): ....

....

In Trial (3): ....

....

Conservation of Momentum in Elastic collision

Table 2: M_{cart_1} = ...( )*, M_{cart_2} = ...( )*

Trial	M_1 ( )*	M_2 ( )*	v_{1_i} ( )**	v_{1_f} ( )**	v_{2_i} ( )**	v_{2_f} ( )**	$P_{Total_i} = M_1 v_{1_i} + M_2 v_{2_i}$ ( )	$P_{Total_f} = M_1 v_{1_f} + M_2 v_{2_f}$ ( )	%Error= $\left\| \frac{\|P_{T_i}\| - \|P_{T_f}\|}{\|P_{T_i}\| + \|P_{T_f}\|} \right\| \times 100$
Trial 1 cart 1$\mapsto$Empty cart 2$\mapsto$Empty									
Trial 2 cart 1$\mapsto$Empty cart 2$\mapsto$+500g									
Trial 3 cart 1$\mapsto$+Empty cart 2$\mapsto$+750g									

Remarks: $*$ The units of mesurements of mass should be converted from (g) to (kg).

$**$ The units measurements of velocity should be converted from (cm/s) to (m/s).

Measurements:

Trial 1: $K_{total_i} = \frac{1}{2}M_1 v_{1_i}^2 + \frac{1}{2}M_2 v_{2_i}^2 =$ .... , $K_{total_f} = \frac{1}{2}M_1 v_{1_f}^2 + \frac{1}{2}M_2 v_{2_f}^2 =$ ....

Trial 2: $K_{total_i} = \frac{1}{2}M_1 v_{1_i}^2 + \frac{1}{2}M_2 v_{2_i}^2 =$ .... , $K_{total_f} = \frac{1}{2}M_1 v_{1_f}^2 + \frac{1}{2}M_2 v_{2_f}^2 =$ ....

Trial 3: $K_{total_i} = \frac{1}{2}M_1 v_{1_i}^2 + \frac{1}{2}M_2 v_{2_i}^2 =$ .... , $K_{total_f} = \frac{1}{2}M_1 v_{1_f}^2 + \frac{1}{2}M_2 v_{2_f}^2 =$ ....

Kuwait University **Physics Department**

Physics Lab 105 & 125
Student Number:
Student Name:
Date:

Explosion and Elastic Collision

- For any given Trial. Check whether linear momentum is conserved?

  ....

- For any given Trial. Check whether kinatic energy is conserved?

  ....

- Based on the results obtained in Table 2, Please write a comment on the direction of motion of cart 1 befor and after the collision.

In Trial (1): ....

....

In Trial (3): ....

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Discussion and conclusion:

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Kuwait University Physics Department
Physics 105 & 125

Torque of Parallel and Non-parallel Forces

Objectives

The objective of this experiment is to study the equilibrium conditions of rigid body and to analyze the torque produced by both parallel and non-parallel forces on a beam balance (lever).

Equipment

- introductory Mechanics System with experimental board, Balance Arm and Protractor assembly.
- Pulley, Mounted Spring Scale, Mass and Hanger Set.

Theory

We have seen earlier in experiment (6) th condition that needs to be satisfied in order to get static equilibrium of forces for a point mass. This condition is:

$$\Sigma F_{x_i} = 0 \quad , \quad \Sigma F_{y_i} = 0 \tag{1}$$

for a *extended rigid body* this condition remains valid if we apply it to the center of gravity. If the rigid body is free to rotate however, there is an additional condition that needs to be satisfied for equilibrium that is:

$$\Sigma \vec{\tau}_i = 0 \tag{2}$$

Where $\vec{\tau}_i$ is the torque produced by force F_i about the rotating point of the rigid body and hence it can be identified as a "turning agent". Figure 1 shows a force **F** acting on a beam that is free to rotate about an axis. The force is applied at point **P**, whose position is defined by the vector $\vec{r}$.

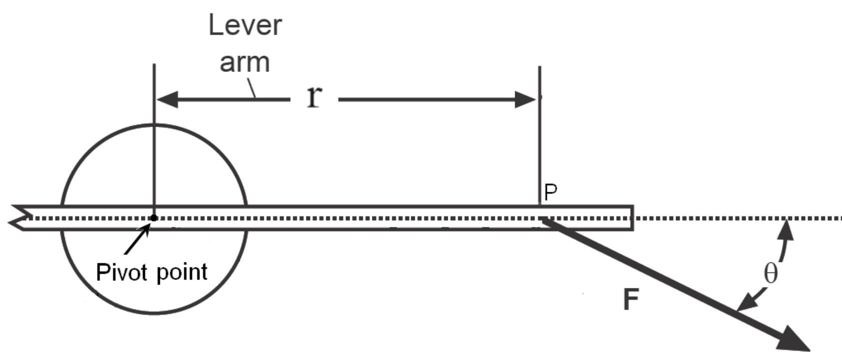

Figure 1. Torque of force **F** about a rotating point.

The angle θ is the angle the force **F** makes with the direction of the arm vector $\vec{r}$. The torque τ is defined as:

$$\vec{\tau} = \vec{r} \times \vec{F} \quad \text{with magnitude} \quad \tau = r\ F\ sin(\theta) \tag{3}$$

In this experiment the rotating point is the pivot. If the sum of all torques is equal to zero then the lever remains in equilibrium. If the net torque is not equal to zero then the beam starts to rotate.

Procedure

Parallel forces

1) For balancing the beam, **setup** the equipment as shown in Figure 2. **Loosen** the thumbscrew on the base and **adjust** the beam so that the zero mark on the beam is aligned with the indicator marks on the pivot. When the beam is level, the bubble in the bubble level will be midway between the two lines on the level.

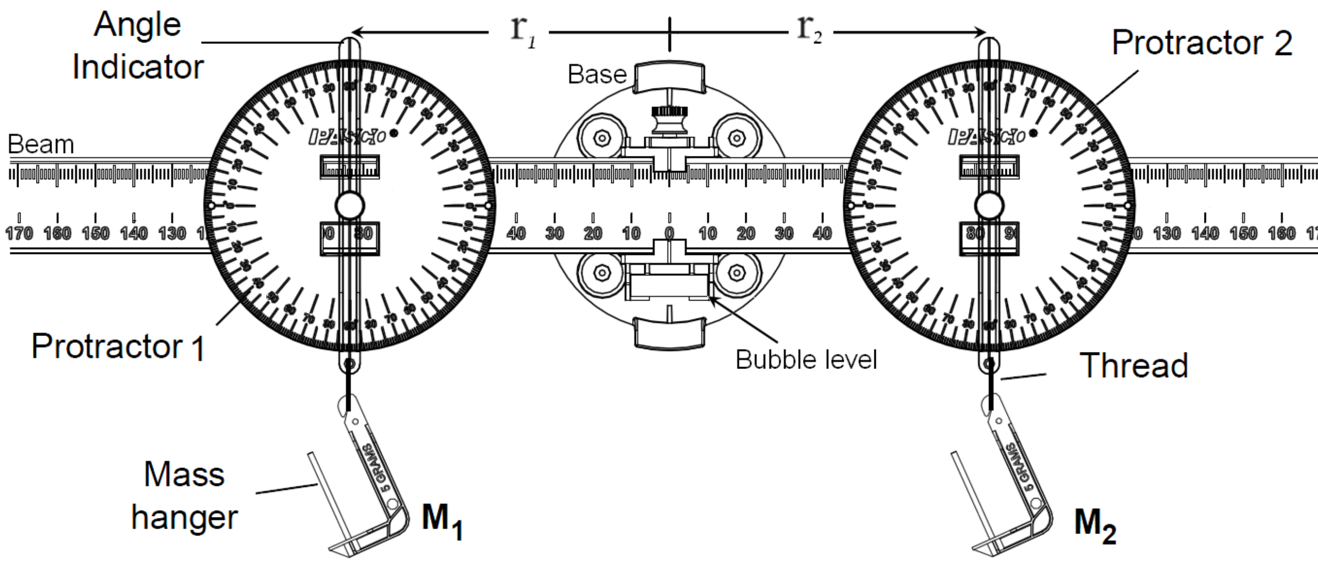

Figure 2. Experimental setup for Torque of Parallel Forces.

2) **Find** the mass of the two protractor used by the triple balance or the digital balance and **record** their masses. **Loosen** the thumbscrew on the two protractors and slide one onto each end of the beam. **Tie** a mass hanger to the thread on the angle indicator of each protractor.

3) **Mount** the Balance beam with the attached base near the center of the Statics Board.

4) **attache** masses M_1 and M_2 and **Position** one of the protractors near one end the beam and **tighten** its thumbscrew to hold it in place. **Adjust** the position of the other protractor until the beam is perfectly balanced, and then tighten its thumbscrew to hold it in place.

5) **Measure** r_1 and r_2, the distances from the pivot to the center of each protractor and **record** all readings in Table 7.1.

6) **Vary** M_1 and M_2 and repeat your measurements for different masses.

7) **Use** $F = M_{total}\, g$ where g is the acceleration due to gravity to determine the weight force of the hanging masses (M_{total}) and **calculate** the torques.

Non-parallel forces

1) **Mount** the Balance beam on the left half of the Statics Board. **Adjust** the beam so that the zero marks on the beam align with the indicator marks on the pivot. **Put** a protractor on each end of the beam as shown in Figure 3.

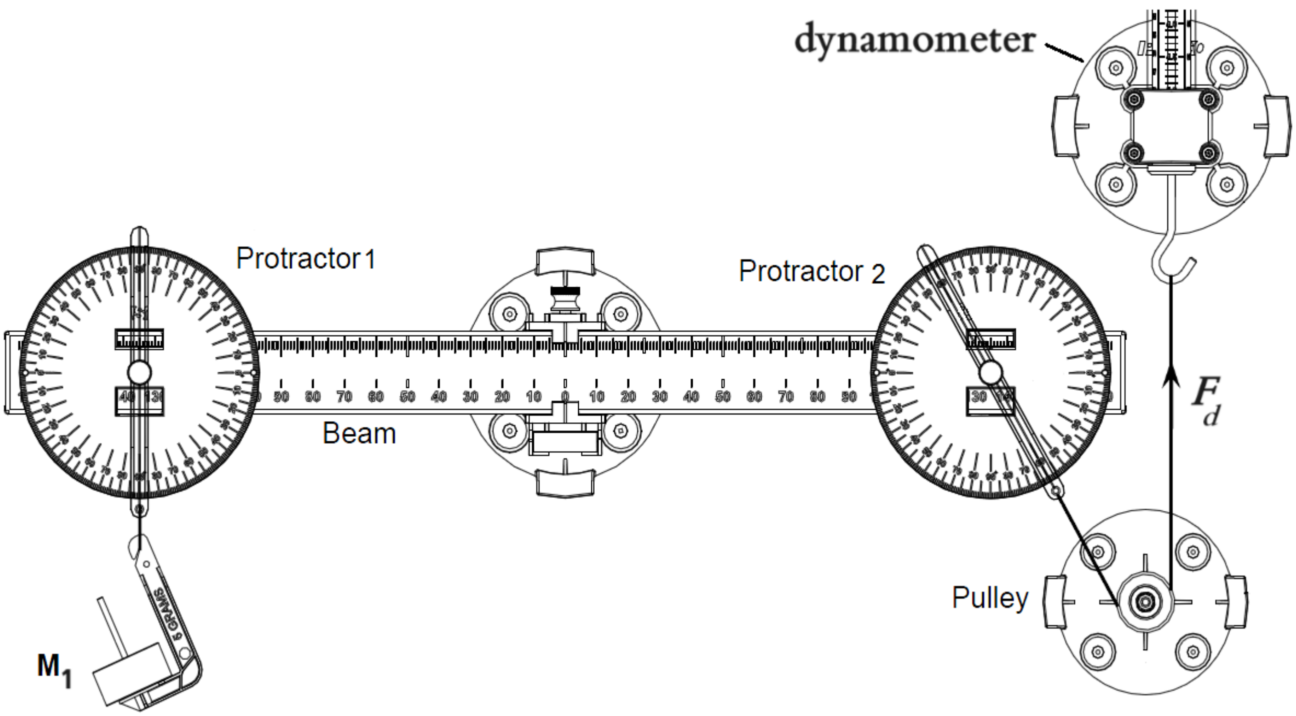

Figure 3. Experimental setup for Torque of Non-Parallel Forces.

2) **Use** a hanging mass and the dynamometer to apply forces $\vec{F_1}$ and $\vec{F_d}$ as illustrated in Figure 3 above.

3) **Fix** the value of r_d to $100mm$, and **Measure** r_1 and **record** these values in Table 2.

4) **Record** M_1 and F_1 of the hanging mass in Table 2. and **Calculate** the torque of force F_1 about the pivot point.

5) By moving the pulley, you can adjust the angle θ of the force F_d.

6) **Set** the angle θ to 45^o. **Move** the dynamometer towards or away from the pulley as needed so that the magnitude of F_d is sufficient to balance the beam, then **record** the reading on the newton scale of the dynamometer.

7) **Calculate** the torque (τ_2) provided by the dynamometer about the pivot point.

8) **Compute** the percentage difference between τ_1 and τ_2.

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Experiment ( ): _

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Instructor name: _

Partners: _

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Total Mark

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Torque of Parallel and Non-parallel Forces

Objectives:

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Torque of Two Parallel forces

The mass of protractors: $M_{protractor_1} =$ .... , $M_{protractor_2} =$ ....

M_1 ( )	r_1 ( )	$F_1 = M_{total_1}\, g$ ( )	$\tau_1 = F_1\, r_1$ ( )	M_2 ( )	r_2 ( )	$F_2 = M_{total_2}\, g$ ( )	$\tau_2 = F_2\, r_2$ ( )
55				75			
45				85			
155				65			
135				55			
75				75			

Note that: $M_{total_1} = M_1 + M_{protractor_1}$, and $M_{total_2} = M_2 + M_{protractor_2}$.

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Torque of Parallel and Non-parallel Forces

- Compare τ_1 and τ_2 and check the equilibrium condition equation (2).

....

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- From your results, what mathematical relationship must there be between τ_1 and τ_2 in order for the beam to be balanced?

....

Torque of Two Non-Parallel forces

The mass of protractors: $M_{protractor_1}$ = ... , $M_{protractor_2}$ = ...

M_1 (g)	r_1 ( )	$F_1 = M_{total_1}\, g$ ( )	$\tau_1 = F_1\, r_1$ ( )	F_d ( )	r_d (mm)	θ (deg)	$\tau_2 = F_d\, r_d\, sin(\theta) + M_{prot_2}\, g\, r_d$ ( )	%Error= $\frac{\lvert\tau_1\rvert - \lvert\tau_2\rvert}{\lvert\tau_1\rvert + \lvert\tau_2\rvert} \times 100$
105					100	45^o		
135					100	45^o		
165					100	45^o		
195					100	45^o		
225					100	45^o		

Note that: $M_{total_1} = M_1 + M_{protractor_1}$.

Kuwait University **Physics Department**

Physics Lab 105 & 125 *Student Number:*

Student Name: *Date:*

Torque of Parallel and Non-parallel Forces

Discussion and conclusion:

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Kuwait University Physics Department
Physics 105 **only**

Rotational motion I

Objectives

The objective of this experiment is to study rotational kinematics (uniformly accelerated rotational motion) and to learn how to measure moment of inertia of a rotating disk and to verify that the experimental value of moment of inertia is consistent with the corresponding theoretical value.

Equipments:

- Setup for Circular Motion (Cast Iron "A" base with rotating shaft, aluminum track, a 300g square mass with thumbscrew, rotating disk, mass hanger, mass pieces, string with hook, mounting rod with pulley).
- Measuring devices:

  Smart Timer.

  Ruler (For the dimensions of the rotating disk).

  Vernier caliper (For the radius of the vertical pulley).

Theory

Newton's second law for uniformly accelerated rotational motion is stated as

$$\tau = I\alpha \qquad (1)$$

where I is the *moment of inertia* of the rotating solid disk about the axis of rotation, α is the angular acceleration of the disk, and τ is the net *torque* applied to it. In order to compute the experimental value of the moment of inertia I of the solid disk, then we should determine first the experimental value of both its angular acceleration α and the amount of torque τ applied to it.

- To determine the angular acceleration α of the disk we will consider the following equation
$$\Delta\theta = \omega_o t + \frac{1}{2}\alpha t^2 \tag{2}$$
with initial conditions $\theta_o = 0$ and $\omega_o = 0$. Hence, Equation (2) is reduced to
$$\theta = \frac{1}{2}\alpha t^2 \tag{3}$$
which implies the fact the α is determined by studying the relation between the angular position (θ) and the time of revolution (t).

- To determine the torque τ applied to the rotating disk (Figure 1), you should keep in mind that this torque is due to the tension of the string wrapped around the vertical pulley.

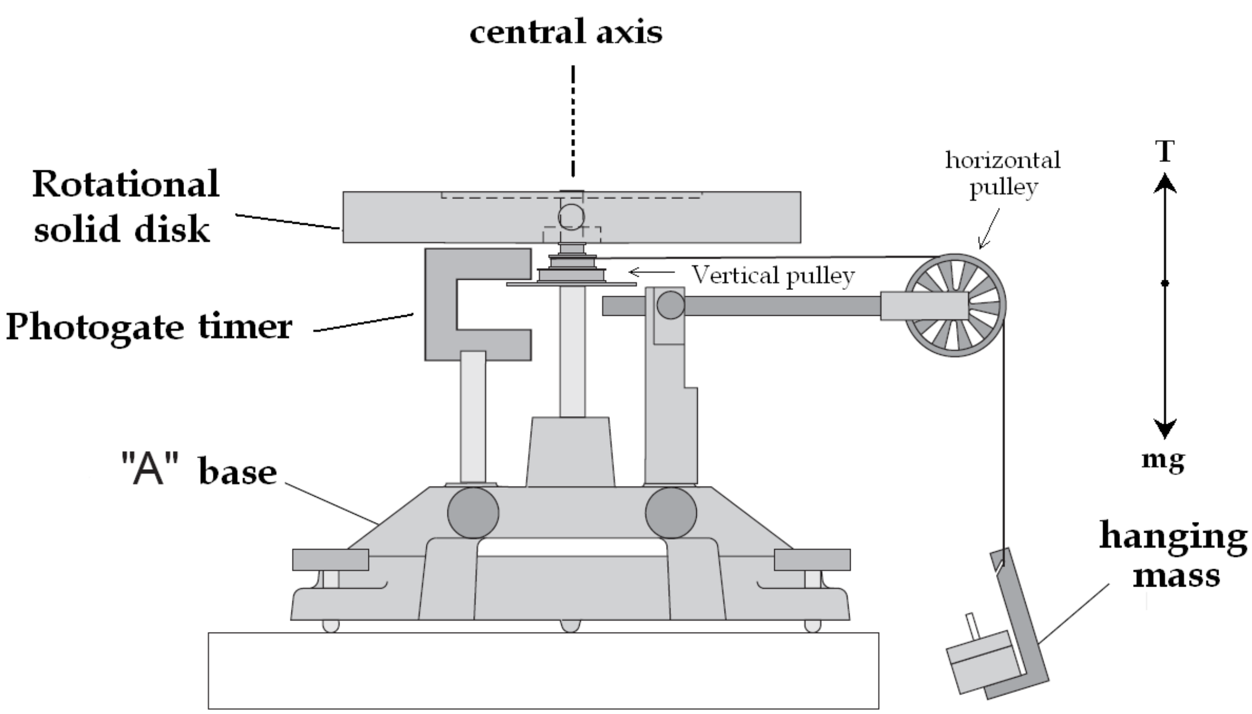

Figure 1. Rotational Apparatus and Free-Body Diagram

Utilizing the definition of torque studied earlier in experiment 8, the torque is identified as:

$$\vec{\tau} = \vec{r} \times \vec{F} \quad \text{with magnitude} \quad \tau = r\ F\ sin(\theta) \tag{4}$$

where $F = m_e g$ represents the magnitude of the force (weight of the effective mass m_e) applied to the vertical pulley and causes it to rotate. The term (r) is the moment arm and it represents the radius of the vertical pulley $(r = R_{vp})$ mounted on the vertical shaft. Because the theory used to find the rotational inertia experimentally does not include friction then you should find out how much mass over the horizontal pulley is needed to overcome the static friction and allow the hanging mass to drop at a constant speed. We refer to this mass as "friction mass" m_f and it will be subtracted from the hanging mass m_h used to accelerate the apparatus. therefore, $(m_e = m_h - m_f)$. Thus, we can write:

$$\tau = (R_{vp})(m_e\, g) sin(90^o) \tag{5}$$

The experimental value of the moment of inertia I of the solid disk is compared to the Theoretical moment of inertia $I_{theoretical}$ of the disk about its central axis which is given by

$$I_{theocratical} = \frac{1}{2} M_d R_d^2 \tag{6}$$

where M_d is the mass of the solid disk and R_d is its radius.

Procedure:

Leveling the "A" Base

1) **Set up** the equipment according to Figure 2.

2) **Attach** the 300g square mass onto either end of the aluminum track and tighten the thumbscrew.

3) **Adjust** the leveling screw on the right leg of the base until the end of the track with the square mass is aligned over the leveling screw of the left leg of the base.

4) **Rotate** the track 90^o so it becomes parallel to the right side of the "A" base and adjust the other leveling screw until the track remains at rest in this position.

5) The track should remain at rest regardless of its orientation otherwise **repeat** steps 3 and 4.

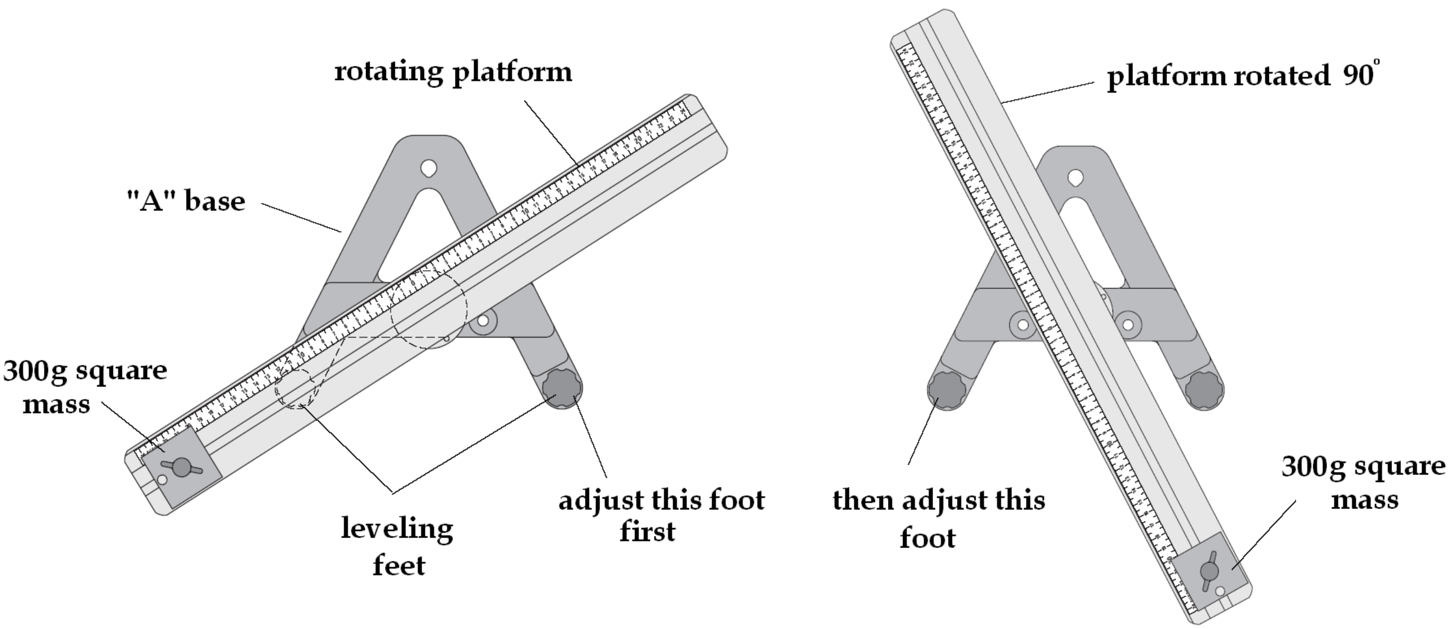

Figure 2. Leveling the "A" base

Moment of Inertia of a Solid Disk

1) **Set up** the rotating apparatus as shown in Figure 1 with the disk placed onto the vertical shaft.

2) Using a hook, **fix** the string to the hole in the vertical pulley and **wind** the string around that pulley by rotating the disk. The total length of the string should deliver a suitable height h, for which the disk can make at least 10 revolutions before the hanging mass falls to the ground.

3) **Use** the free spoke of the vertical pulley and the photogate timer to measure the period of each revolution of the disk.

4) For measuring of the periods, **Press** the "Select Measurement key" on the Smart Timer until the word **Time** is displayed on the top line of the display. **Press** the "Select Mode key" until the **Fence** mode is displayed after the measurement type. **press** the "Start/Stop" to begin. You will hear a beep, and a asterisk (*) will appear on the second line of the display.

5) **Release** the disk from rest and allow the hanging mass to reach the ground. The Smart timer will show all readings on the periods automatically. **Record** the all data in Table 1.

6) **Plot** the graph of the angular position θ versus t^2. **Determine** the angular acceleration from this graph and then **calculate** the moment of inertia of the disk using Equation (1).

7) **Compare** the experimental value of the moment of inertia of the disk with the theoretical value calculated.

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Experiment ( ): _

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*Student name:*_ *Student number:*_ _ _ _ _ _ _ _ _ _ _

Instructor name: _

Partners: _

_ _

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Total Mark

Kuwait University **Physics Department**

Physics Lab 105 only

Student Number:

Student Name:

Date:

Rotational motion I

Objectives:

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- **Measure** and **record** the following parameters:
  - ∗ The radius of the rotating disk R_d = ...
  - ∗ The mass of the disk M_d = ...
  - ∗ The radius of the vertical pulley R_{vp} = ...
  - ∗ The friction mass m_f = ...
  - ∗ The hanging mass m_h = ...
  - ∗ The effective mass m_e = ...
  - ∗ The torque τ using equation (4)= ....
  - ∗ The moment of inertia of the disk using equation:

    $(I_{theoretical} = \frac{1}{2} M_d R_d^2)$ = ...

Kuwait University **Physics Departement**

Physics Lab 105 only

Student Number:

Student Name:

Date:

Rotational motion I

Table 1.

n (rot)	$\theta = 2\pi n$ ( )	t ( )	t^2 ( )
1		$t_1 =$	
2		$t_{1+2} =$	
3		$t_{1+2+3} =$	
4		$t_{1+2+3+4} =$	
5		$t_{1+2+3+4+5} =$	
6		$t_{1+2+3+4+5+6} =$	
7		$t_{1+2+3+4+5+6+7} =$	
8		$t_{1+2+3+4+5+6+7+8} =$	
9		$t_{1+2+3+4+5+6+7+8+9} =$	
10		$t_{1+2+3+4+5+6+7+8+9+10} =$	

Angular acceleration α (from the graph)= ....

Experimental value of I (from Equation 1) = ...

Theoretical value of I (from Equation 5) = ...

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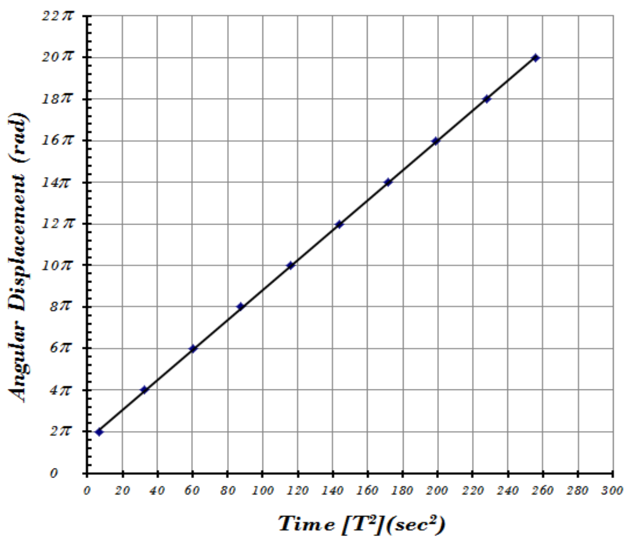
Physics Lab 105 only *Student Number:*

Student Name: *Date:*

Rotational motion I

Plot the following graph:



Slope = ...

α = 2 x Slope = ...

$I = \frac{\tau}{\alpha}$ = ...

Percentage error in the value of I obtained:

$$\left|\frac{I_{theoretical} - I_{expreimental}}{I_{theoretical}}\right| \times 100 = \ldots\ldots\ldots\ldots\ldots\ldots$$

Discussion and conclusion:

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Kuwait University Physics Department
Physics 105 only

Rotational motion II

Objectives

The objective of this experiment is to study rotational kinetic energy and to verify the conservation of mechanical energy in the absence of frictional forces.

Equipments:

- Setup for Circular Motion (Cast Iron "A" base with rotating shaft, aluminum track, a 300g square mass with thumbscrew, rotating disk, mass hanger, mass pieces, string with hook, mounting rod with pulley).
- Measuring devices:

  Photogate timer.

  Ruler (For the dimensions of the rotating disk).

  Vernier caliper (For the radius of the vertical pulley).

Theory

Mechanical energy (E) is the sum of the potential and kinetic energies in a system. The principle of the conservation of mechanical energy states that the total mechanical energy in a system (i.e., the sum of the potential plus kinetic energies) remains constant as long as the only forces acting on the system are conservative forces. Consequently;

$$\Delta E = 0 \implies E_i = E_f \tag{1}$$

where i represent the initial energy of the system before the motion and f represent the energy of the same system after the motion. As illustrated in Figure 1 below, the investigated physical system is a system that consists of two moving objects. Namely, the rotational solid disk that rotates sagittally about its central axis and effective hanging mass (m_e) that moves in translational motion toward the earth surface.

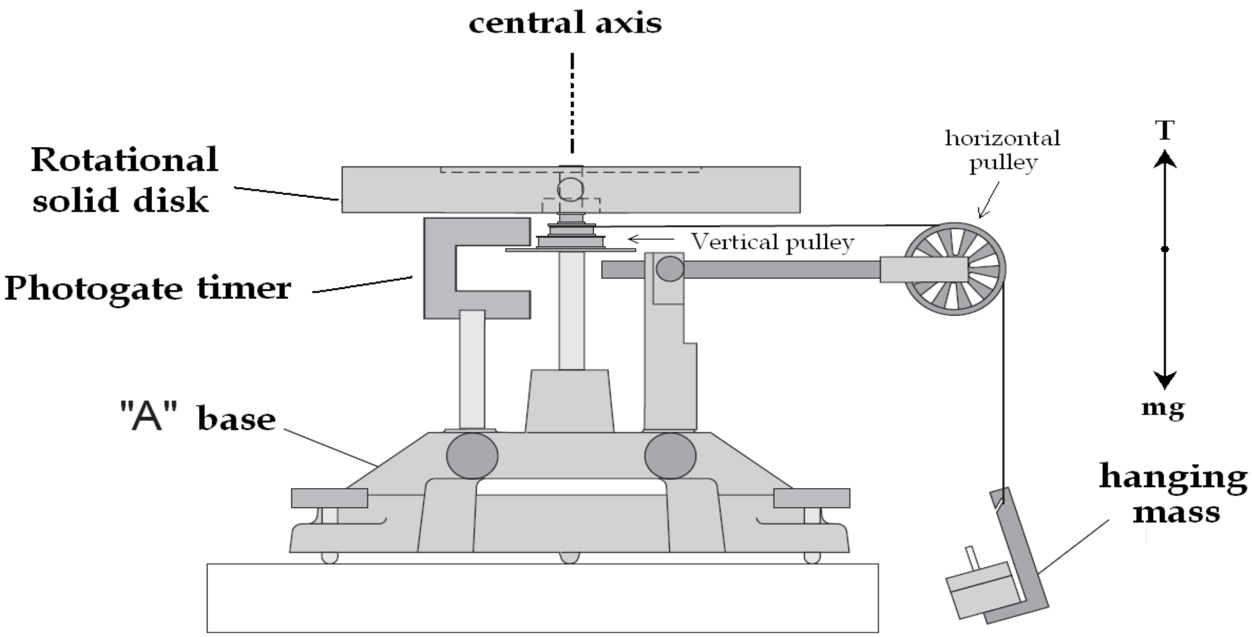

Figure 1. Rotational Apparatus and Free-Body Diagram

Therefore, the total initial mechanical energy of this system is written as :

$$E_{T_i} = \left(U_{g_{(disk)_i}} + U_{g_{(m_e)_i}}\right) + \left(K_{(disk)_i} + K_{(m_e)_i}\right)$$

$$= 0 + m_e gh + \frac{1}{2}I\omega_o^2 + \frac{1}{2}m_e v_o^2 = m_e gh$$

where U_g is the gravitational potential energy of both objects in the system, $K_{(disk)_i}$ is the initial rotational kinetic energy of the solid disk that is expressed in terms of moment of inertia (I) and initial angular velocity (ω_o) of the disk. The term $K_{(m_e)_i}$ is the initial translational kinetic energy of the effective hanging mass as it starts to move with initial velocity (v_o) downward toward the ground. If the hanging mass starts falling from rest at a height h above the ground then $v_o = 0$ and $\omega_o = 0$.

Similarly, the total final mechanical energy of the system is written as:

$$E_{T_f} = \left(U_{g_{(disk)_f}} + U_{g_{(m_e)_f}}\right) + \left(K_{(disk)_f} + K_{(m_e)_f}\right)$$
$$= 0 + 0 + \frac{1}{2}I\omega_f^2 + \frac{1}{2}m_e v_f^2$$

Therefore, by substituting these results back in equation (1) above we conclude that the conservation of mechanical energy requires:

$$m_e g\, h = \frac{1}{2}I\omega_f^2 + \frac{1}{2}m_e v_f^2 \tag{2}$$

however, the translational kinetic energy K_{trn} of the falling mass is very small (almost negligible) then the chose to ignore it. That reduces Equation (8) to

$$m_e g\, h \simeq \frac{1}{2}I\omega_f^2 \tag{3}$$

The theoretical moment of inertia $I_{theoretical}$ of the disk about its central axis which is given by

$$I_{theocratical} = \frac{1}{2}M_d R_d^2 \tag{4}$$

where M_d is the mass of the solid disk and R_d is its radius.

Procedure:

Leveling the "A" Base

1) **Set up** the equipment according to Figure 2.

2) **Attach** the 300g square mass onto either end of the aluminum track and tighten the thumbscrew.

3) **Adjust** the leveling screw on the right leg of the base until the end of the track with the square mass is aligned over the leveling screw of the left leg of the base.

4) **Rotate** the track 90^o so it becomes parallel to the right side of the "A" base and adjust the other leveling screw until the track remains at rest in this position.

5) The track should remain at rest regardless of its orientation otherwise **repeat** steps 3 and 4.

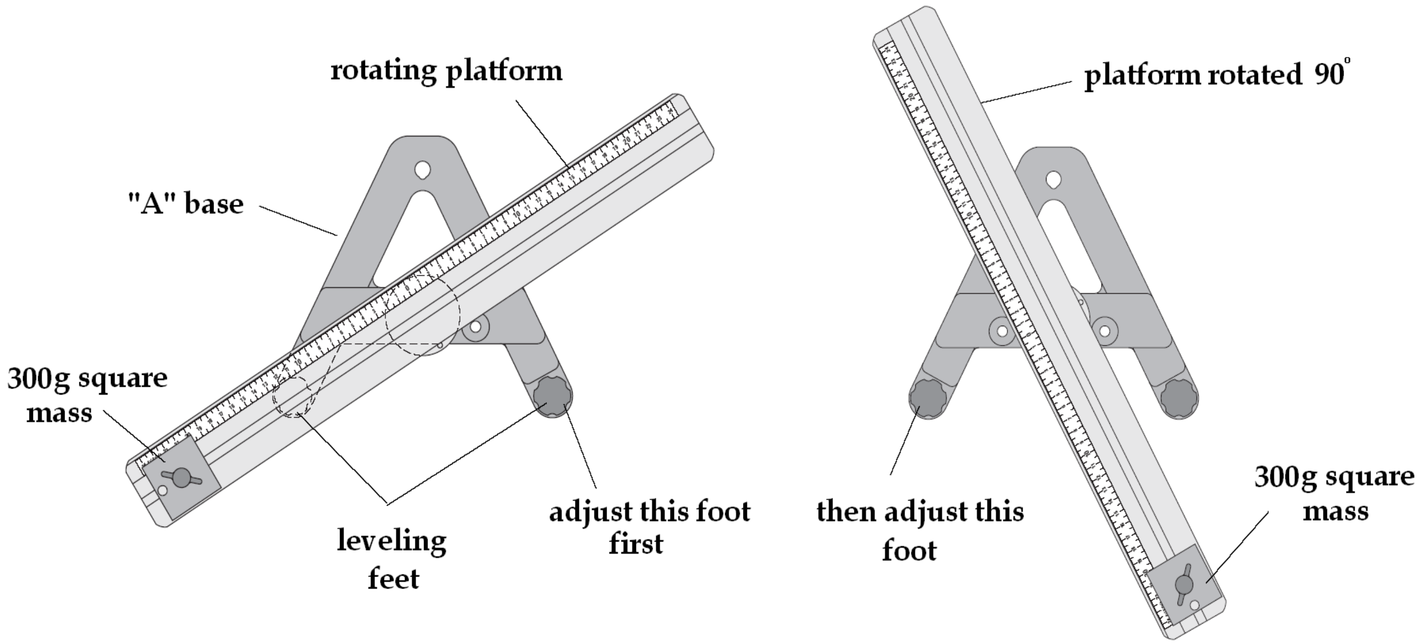

Figure 2. Leveling the "A" base

Conservation of Mechanical Energy

1) **Set up** the rotational apparatus as shown in Figure 1.

2) **Measure** the falling distance h and **record** it in Table 1. **Adjust** the length of the string such that at the moment the falling mass hits the ground, the hook would be released automatically from the threaded hole.

3) **Set** the photogate timer to **pulse** mode and **measure** the period T_f in the phase of uniform motion just after the acceleration phase is over. **Record** it Table 1.

4) **Calculate** the angular speed $\omega_f = \frac{2\pi}{T_f}$ and **record** it in Table 1.

5) **Repeat** the previous steps for other hanging masses given in Table 1.

6) **Plot** a graph of the rotational kinetic energy versus initial potential energy of the effective mass. You should get a straight line through the origin with slope equal to 1.

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Course / Section:_ _ _ _ _ _ _ _ _

Student Serial Number:

Physics Department

Date: [ ] [ ] [ ]
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Experiment ( ): _

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Instructor name: _

Partners: _

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Total Mark

Kuwait University **Physics Department**

Physics Lab 105 only *Student Number:*

Student Name: *Date:*

Rotational motion II

Objectives:

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- **Measure** and **record** the following parameters:
  - ∗ The radius of the rotating disk $R_d =$ ....
  - ∗ The mass of the disk $M_d =$ ....
  - ∗ The friction mass $m_f =$ ....
  - ∗ The Falling height $h =$ ....
  - ∗ The moment of inertia of the disk using equation (5)= ....

Table 1. Conservation of Mechanical Energy

m_h (g)	$m_e = (m_h - m_f)$ ( )	$U_{g_{(m_e)_i}} = m_e g h$ ( )	T_f ( )	$\omega_f = \frac{2\pi}{T_f}$ ( )	$K_{disk_f} = \frac{1}{2} I \omega_f^2$ ( )
17					
20					
23					
26					
29					
55					

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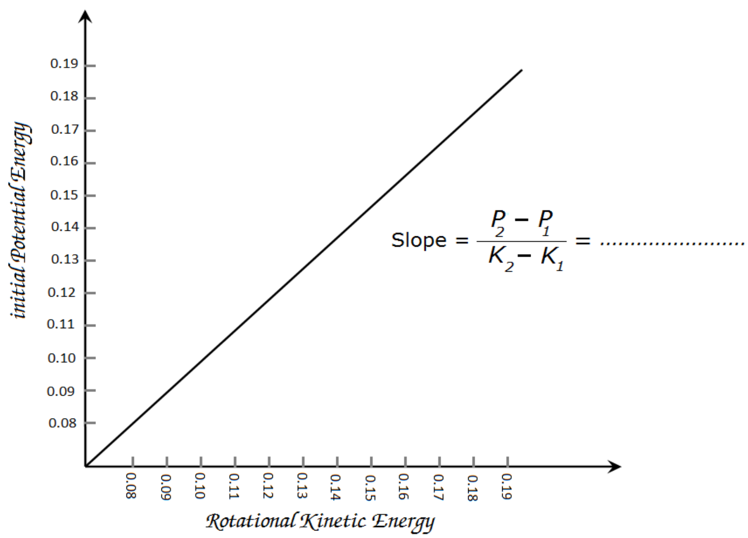
Physics Lab 105 only *Student Number:*

Student Name: *Date:*

Rotational motion II

Plot the graph of Potential energy Vs. Rotational Kinetic energy:



Discussion and conclusion:

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Physics 125 only

Velocity of Sound

Objectives

The objective of this experiment is to study the Phenomenon of Resonance in a column of air, and use its result to determine the velocity of sound in air at room temperature.

Equipments:

- Resonance Tube apparatus (Figure 1).
- Open Speaker.
- Sine Wave Generator.

Theory

The velocity with which sound travels in a medium may be determined if the frequency and the wavelength are known. This relation is shown in the equation:

$$V = f\lambda \tag{1}$$

where, V is the velocity of sound propagation, f is the frequency, and λ is the wavelength. In this experiment the velocity of sound in air is to be found by using a The Resonance tube setup that includes an open speaker driven by a Sine wave generator (Figure 1) to produce a sound wave whose length will be measured by means of a resonating column of air.

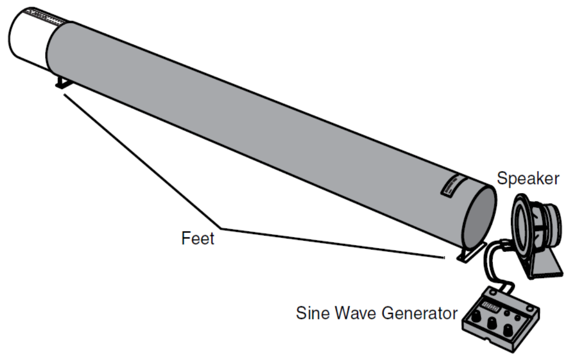

Figure 1. Experimental Setup.

The tube set includes an outer tube and an inner tube with a scale and a removable plug. The length of the air column is adjusted by moving the inner tube (Figure 2). When the plug is in place, the tube is closed at one end. Without the plug, the tube is open at both ends. There are two rows on the scale: one for measuring the resonating length when the plug is in place and one for when the plug is removed The tube is driven by a speaker.

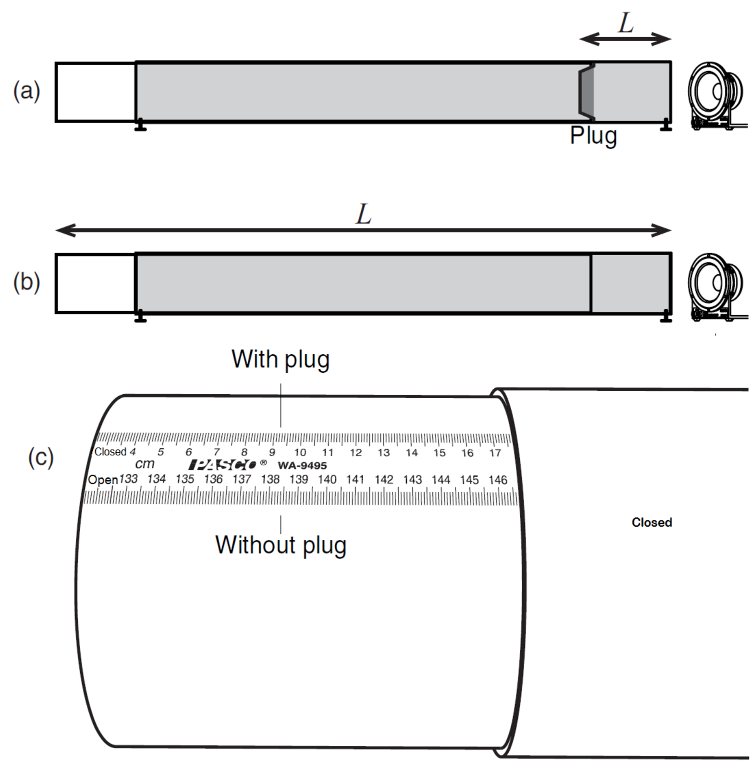

Figure 2. (a) Closed-end tube with plug, (b) Open-end tube with the plug removed,
(c) Closed-end length is measured on top scale; open-end length is measured on the bottom scale.

When sound waves propagate down the tube, they are reflected at the closed end and stationary vibrations of air molecules are produced due to the interference of the incident and reflected wave trains. The air column will then vibrate strongly in segments with a frequency. Only If the frequency of vibration of the air column is equal to the frequency of the speaker a **Resonance** occurs. This is indicated by the sudden increase in the intensity of the sound when the column is adjusted to the proper length. At the closed end of the tube the incident and the reflected waves interfere in such a way that their amplitudes cancel each other out then the air molecules remains at rest and this defines a **Node** (Figure 3). **Antinode**, however; occurs at a short distance e (known as the end correction) above the open end of the tube where the incident and the reflected waves reinforce each other.

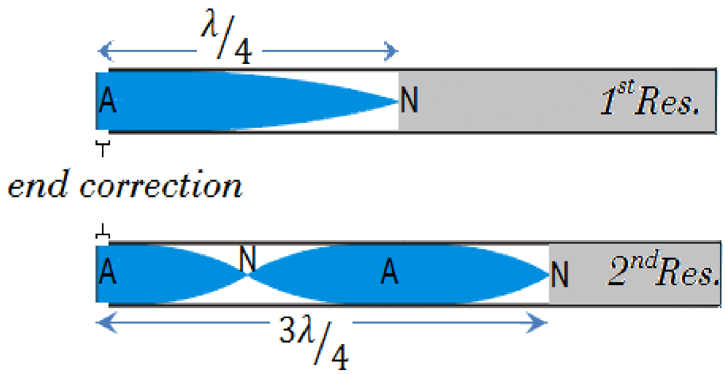

Figure 3. Standing wave in the air column of a closed end tube.

Figure 3 indicates the conditions of vibration for the first two positions of resonance, from which we have :

$$L_1 + e = \frac{\lambda}{4} \tag{2}$$

$$L_2 + e = \frac{3\lambda}{4} \tag{3}$$

by subtraction we can find λ in terms of L_1 and L_2. Substituting this result back in equation (1) we get the experimental value of speed of sound:

$$V_{experimental} = 2f(L_2 - L_1) \tag{4}$$

This experimental value of V can be compared to the result calculated from the formula:

$$V_t = V_0\sqrt{1+\frac{t}{273}} \qquad (5)$$

where V_o= 331 m/s, which is the velocity of sound in air at 0^o C temperature and t is the current room temperature. The value of the end correction e for the tube can be calculated :

$$e = \frac{1}{2}(L_2 - 3L_1) \qquad (6)$$

Procedure

1) **Set up** the equipment as illustrated in Figure 4 with the plug is installed on the end of the inner tube closest to the speaker.

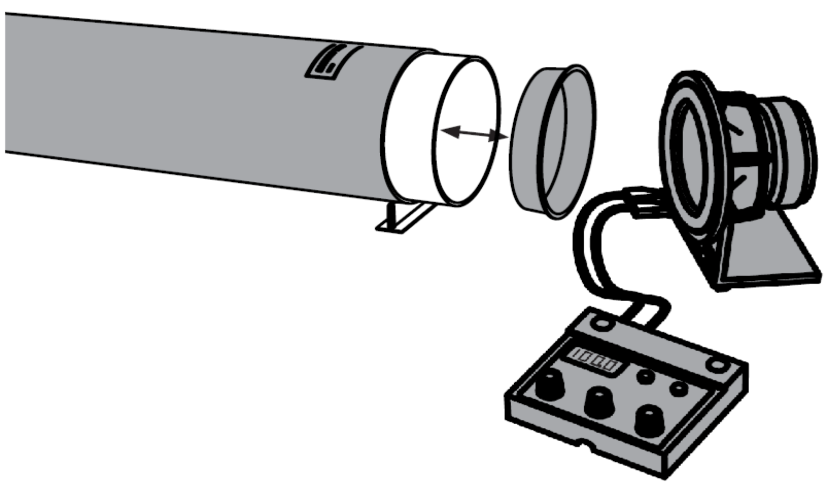

Figure 4. How to remove or replace Plug.

2) **Position** the speaker such that it is facing the plug and the tube and only at few centimeters away from the plug.

3) Using the Sine wave generator, **Drive** the speaker at a constant frequency of 250 Hz.

4) Slowly **increase** the length of the air column by pulling the inner tube away from the speaker until the air column resonates producing a maximum sound.

5) **Measure** the length (L_1) of the air column from the "Closed" scale on the inner tube and **Record** in Table 1.

6) **Repeat** steps (3) through (5) one more time and calculate the average value of L_1.

7) **Increase** the length of the air column further by pulling the inner tube away from the speaker until the air column resonates producing a maximum sound for the second time.

8) **Measure** the length (L_2)of the air column from the "Closed" scale on the inner tube and **Record** in Table 1.

9) **Repeat** steps (7) and (8) one more time and **calculate** the average value of L_2.

10) **Repeat** steps (1) through (9) five more times for the five different driven frequencies given in the Table.

11) **Determine** the experimental value of (V) using equation (4) and **compare** it to the theoretical value obtained from equation (5).

12) Only for the last given frequance in Table 1, **determine** the value of the end correction (e) using equation (6).

13) **Plot** the graph of ($\bar{L_2} - \bar{L_1}$) versus ($\frac{1}{f}$). **Calculate** the value of speed of sound (V) from the slope of the graph.

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Partners: _

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Total Mark

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Physics Lab 125 only

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Student Name:

Date:

Velocity of Sound

Objectives:

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Table I.

		1st Resonance			2nd Resonance				
$Frequency\,(f)$ (Hz)	$\frac{1}{f}$ ( )	L_1 ( )	L_1 ( )	$\bar{L_1}$ ( )	L_2 ( )	L_2 ( )	$\bar{L_2}$ ( )	$\bar{L_2} - \bar{L_1}$ ( )	V ( )
250									
280									
310									
340									
370									
400									

∗ Determine the average value of speed of sound in air :

$\bar{V}$ = ...

Kuwait University **Physics Department**

Physics Lab 125 only

Student Number:

Student Name:

Date:

Velocity of Sound

Find the Standard Error:

V_i ( )						
$(V_i$-$\bar{V})$ ( )						
$(V_i$-$\bar{V})^2$ ( )						

∗ Standard deviation:

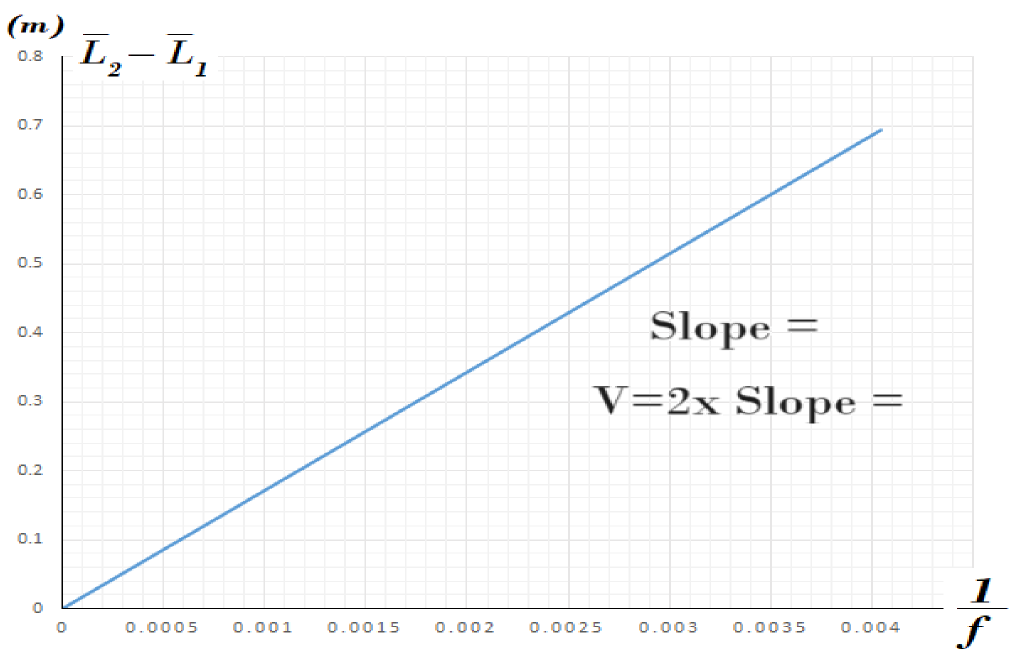
$$(\sigma_V) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{6}(V_i - \bar{V})^2} = \text{................................}$$

∗ Standard Error:

$$(\sigma_{\bar{V}}) = \frac{\sigma_V}{\sqrt{n}} = \text{................................}$$

∗ Result of speed of sound:

$$\bar{V} \pm \sigma_{\bar{V}} = \text{...}$$



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Physics Lab 125 only

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Student Name:

Date:

Velocity of Sound

* The value of speed of sound in room temperature:

$$(V_t) = ...$$

* The value of (V) from the graph:

$$(V_{graph}) = ...$$

* For the last frequancy in Table 1, the value of the end correction (e) by equation (6):

$$(e) = ...$$

* The percentage error of your result is:

$$\%\ Error = \left|\frac{\bar{V} - V_{graph}}{\bar{V}}\right| \times 100 = ...$$

Discussion and conclusion:

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Physics 125 only

Human Arm Model

Objectives

The objective of this experiment is to understand the complex movements of an actual human arm by styding the simulations of the muscles and motion provided by the Human Arm Model. In this model, cords representing the biceps and triceps muscles attach to the arm. Students can pull the cords to make the arm move and use force sensors to measure the forces exerted by the muscles.

Equipment

- Human Arm Model.
- Large Table C-clamp with 45 cm steel Rod.
- Sensor-mounting Studs, 2 pieces, and clamp.
- Two force sensors.
- Mass peices with mass hanger.
- Xplorer-GLX data acquisition unit.

How it works

Cords are used in the human arm model to represent the muscles of the upper arm. Depending on how you will use the model, you can attach one or two cords, use standard cords or elastic cords, and run the cords over and under the pulleys in various ways.

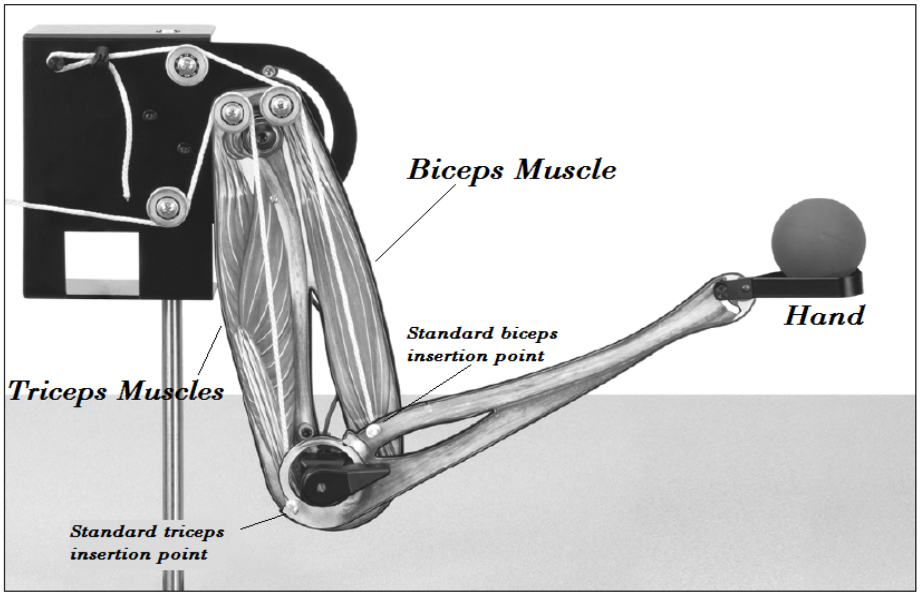

Figure 1. Experimental setup for Human Arm Model.

The biceps cord for example can be attached at the standard muscle insertion point as shown in Figure 1. This in fact mimics the actual representation of the biceps muscle in the human arm. In order to attach the corde you should tie a knot near the end of a cord and insert the other end of the cord through the standard insertion point hole as seen in Figure 2. Pull the cord through until the knot stops against the hole.

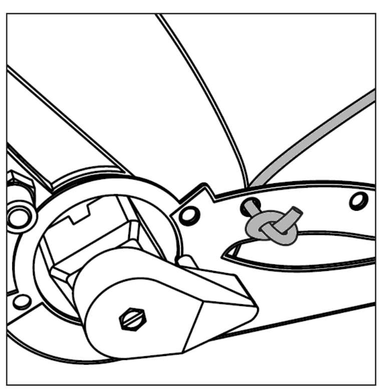

Figure 2. Cord attached to insertion point.

The remaining cord should pass over and under the pulleys in the desired configuration. Use one of the cord locks to make a loop in the free end of the cord. Place the loop over a force sensor hook. Adjust the length of the cord. Push the cord lock against the hook and tie a knot against the cord lock to prevent it from slipping (Figure 3).

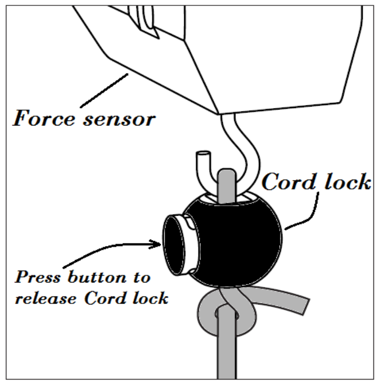

Figure 3. Cord attached to force sensor with cord lock.

The idea in this experiment is to demonistrate to the students how thier arm is going to performe if a load is appied to it while it is hang vertically at their side with upper arm kept vertical and elbow is bent at 90^o so that the forearm is horizontal. on the bases of their results, the students should be able to comment on the amount of biceps force needed to keep the elbow fixed at 90^o and hold a certain weight in their hand. If you double the mass in your hand (so the load force doubles), does the biceps force double?

Procedure

1) **Use** the C-clamp to fix the human arm model vertically on the laboratory table as illustrated in Figure 4.

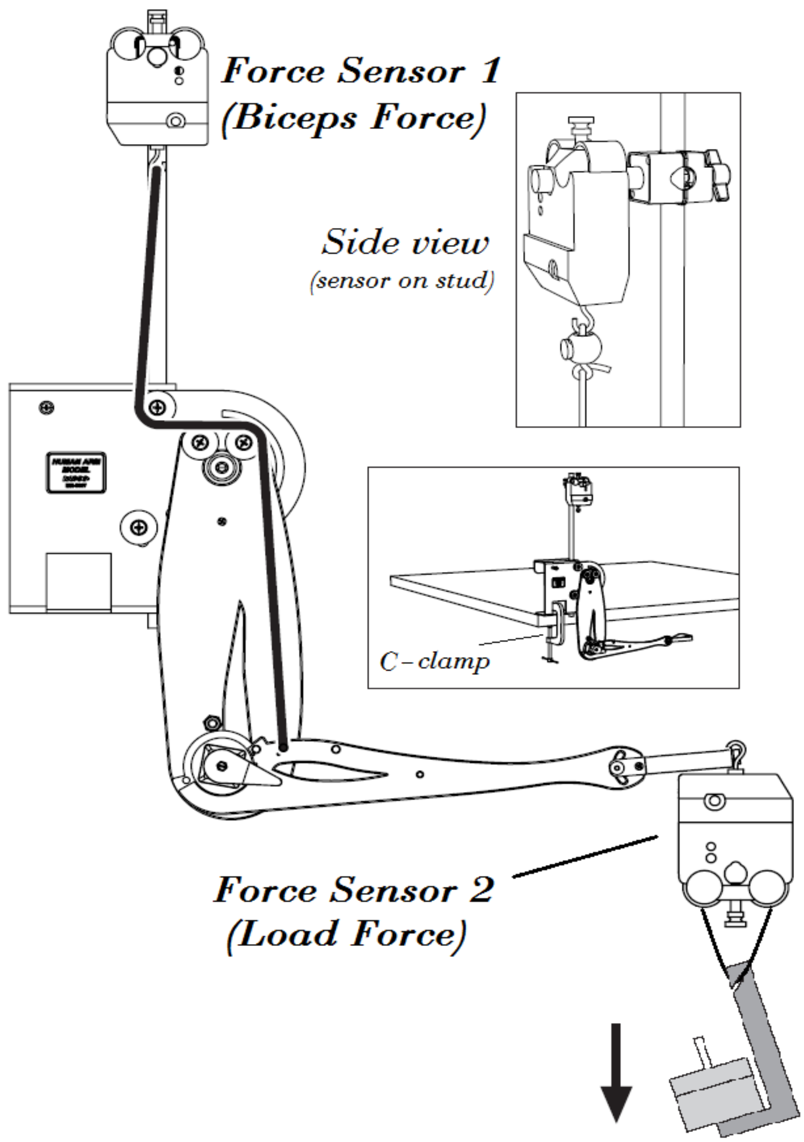

Figure 4. Experimental setup for Human Arm model and Force Sensors.

2) **Fix** the 45cm steel rod to the base of the model as illustrated. **Use** the sensor clamp and stud to attach a force sensor to the steel rod. See Figure 4 above.

3) **Switch "ON"** the X-plorer GLX data acquisition unit by pressing on the (ON/OFF) button shown in Figure 5 below. After ten seconds Main Icons will appear automatically on the Home Screen.

Figure 5. X-plorer GLX data acquisition unit.

4) Using the Arrow keys on the unit, **highlight** the "Digits" icon, which is located on the first row on the Home screen of the unit then press ($\surd$) button. This screen is useful for displaying live data as they are collected from sensors.

5) **Connect** both force sensors to the sensor ports of your X-plorer GLX interface for data acquisition. See Figure5.

6) As you connect Force Sensor 1 (represinting Biceps Force from Figure 4) to sensor port (1) on the X-plorer interface (Figure 5), the screen will change to:

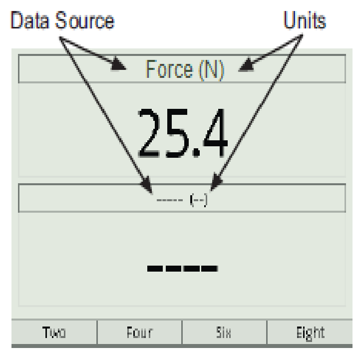

Figure 6. Digits Display on the X-plorer unit.

7) **Connect** the second force sensor 2 to sensor port 2 on the X-plorer interface to measure the force of the applied load.

8) **press** the "Zero" button on both force sensors to reset them both befor stating the experiment.

9) **Apply** the mass to force sensor 2 as indicated in Table I. and **record** both measurements of F_1 and F_2. **Please ignor (avoid) the minus sign in the answer**.

10) **Adjust** the length of the cord in such a way that the forearm is bent almost 45^o above the horizontal. **Repeat** all previuos steps and **record** your data in Table I.

11) **Adjust** the length of the cord once again in such a way that the forearm is bent almost 45^o below the horizontal. **Repeat** all previuos steps and **record** your data in Table I.

9) On the same Graph paper, **plot** the graph of F_1 as a function of F_2 for all three congiguration of the albows angle.

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| day | month | year |

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*Student name:*______________________ *Student number:*___________

Instructor name: _______________________

Partners: __________________________

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Total Mark

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Physics Departement

Physics Lab 125 only

Student Number:

Student Name:

Date:

Human Arm Model

Objectives:

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Table I.

Mass	$\theta = 90^o$		$\theta < 90^o$		$\theta > 90^o$	
	F_1	F_2	F_1	F_2	F_1	F_2
( )	( )	( )	( )	( )	( )	( )
5						
25						
45						
65						
85						
105						
125						
145						
165						
185						
205						
225						
245						
265						
285						

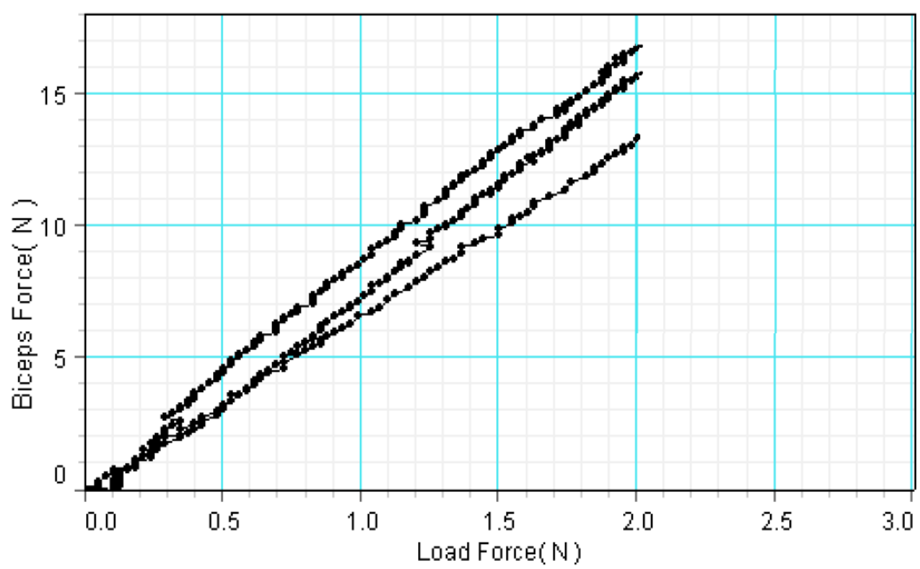
Kuwait University **Physics Departement**

Physics Lab 125 only *Student Number:*

Student Name: *Date:*

Human Arm Model

* Plot the graph of Biceps force (F_1) versus the load force (F_2) for all configration of the elbows angle



Which confuguration of the elbows angle give the most biceps force as comparied to the load force?

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Which confuguration of the elbows angle give the least biceps force as comparied to the load force?

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Physics Lab 125 only

Student Number:

Student Name:

Date:

Human Arm Model

Discussion and conclusion:

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