KING ABDUL AZIZ UNIVERSITY

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Faculty of Science and Art

Physics Department

The Principles of The Experimental Physics

Experimental Lab Physics 281

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Contents:-

Experimental Error and Data Analysis

Introduction

Laboratory investigations involve taking measurements of physical quantities, and the process of taking any measurement always involves some uncertainty or experimental error. Suppose that you and another person independently took several measurement of a physical quantity (e.g., the length of an object). It is unlikely that you both would come up with exactly the same results.

Types of Errors

Experimental errors can be generally classified as being of three types: personal, systematic, and random.

Personal Error

Personal error arises from personal bias or carelessness in reading an instrument, in recording observation, or in mathematical calculations. Examples of personal errors include:

1- Errors in reading a scale.
2- Not observing significant figures in calculations.

Systematic Error

Systematic errors are errors associated with particular measurement instruments or techniques, such as an improperly calibrated instrument or bias on the part of the observer. Conditions from which systematic errors can result include:

1- An improperly zeroed instrument (e.g. balance or ammeter).
2- A thermometer that reads $101\ ^0C$ when immersed in boiling water at standard atmospheric pressure. The thermometer is improperly calibrated since the reading should be $100\ ^0C$.
3- A meter stick that has shrunk due to environmental conditions would always read higher.

Random Error

Random errors are from unknown and unpredictable variations in experimental situations. Random errors are also referred to as accidental errors and are sometimes beyond the control of observer. Conditions by which random errors can result include:

1- Unpredictable fluctuations in temperature or line voltage.
2- Mechanical vibrations of the experimental setup.

3- Unbiased estimates of measurement readings by the observer.

Precision and accuracy

There are different between precision and accuracy. The precision indication of how close individual measurements agree, whereas the accuracy how close individual measurements agree with true value. The less discrepancy between the measured values gives more precision. The less discrepancy between the measured values and true value give more accuracy.

To get a better feeling for the difference between accuracy and precision, let's consider the following shooting-target analogy, as shown in Figure 1. The experiment is to shoot a set of rounds at a stationary target and analyze the results. The results are summarized below.

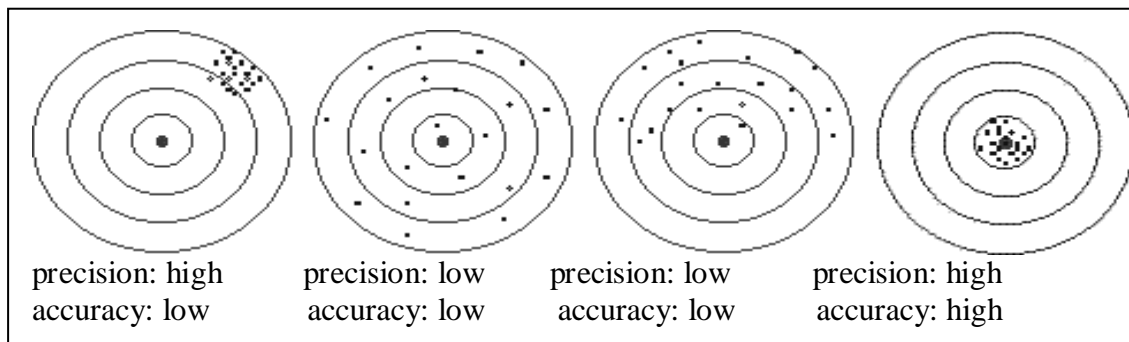| precision: high | precision: low | precision: low | precision: high |
| accuracy: low | accuracy: low | accuracy: low | accuracy: high |

Fig. 1 A scheme diagram shows shooting target

The measurement precision associates with the number of digits that record by a specific measuring instrument. When you take a measurement, you must be recorded all numbers that you read on the tool of measurement without increase or decrease the number. All recorded figures must be confirmed except the first right number that could be estimated.

Uncertainties

All measurements always have some uncertainty. We refer to the uncertainty as the error in the measurement. Errors fall into three categories:

1. Systematic Error: errors resulting from measuring devices being out of calibration. Such measurements will be consistently too small or too large. These errors can be eliminated by pre-calibrating against a known, trusted standard.

2. Personal Error: errors resulting from the person how do the experiment. The person may be not trained on the device or read the measured number error.

3. Random Errors: errors resulting in the fluctuation of measurements of the same quantity about the average. The measurements are equally probable of being too large or too small. These errors generally result from the fineness of scale division of a measuring device.

Physics is a quantitative science and that means a lot of measurements and calculations. These calculations involve measurements with uncertainties and thus it is essential for the physics student to learn how to analyze these uncertainties (errors) in any calculation.

The uncertainty associated with a single measurement (σ_x) when using a scale or digital measuring device considered as the following rule:

1- Uncertainty in a scale measuring device is equal to the smallest increment divided by 2 .

$$\sigma_x = \frac{\text{smallest increment}}{2}$$

Example: Meter Stick (scale device)

$$\sigma_x = \frac{1\text{mm}}{2} = 0.5mm = 0.05cm$$

2- Uncertainty in a digital measuring device is equal to the smallest increment.

σ_x = smallest increment

Example: Digital balance (digital device)

5.4365kg

$\sigma_x = 0.0001$kg

In general, any measurement can be stated in the following preferred form:

measurement = $x_{best} \pm \sigma_x$

Significant Figures

The confirmed and the estimated number called significant figures with the following rules

- Non-zero digits are always significant.
- All zeros between other significant digits are significant.
- The number of significant figures is determined starting with the leftmost non-zero digit. The leftmost non-zero digit is sometimes called the most significant digit or the most significant figure. For example, in the number 0.004205 the '4' is the most significant figure. The left hand '0's are not significant. The zero between the '2' and the '5' is significant.

- The rightmost digit of a decimal number is the least significant digit or least significant figure. Another way to look at the least significant figure is to consider it to be the rightmost digit when the number is written in scientific notation. Least significant figures are still significant! In the number 0.004205 (which may be written as 4.205×10^{-3}), the '5' is the least significant figure. In the number 43.120 (which may be written as 4.3210×10^{1}), the '0' is the least significant figure.
- If no decimal point is present, the rightmost non-zero digit is the least significant figure. In the number 5800, the least significant figure is '8'.

Example: the following table shows the measured value and the number of significant figures.

The individual measurement	The number of significant figures
0.0023	2
1.001	4
0.109800	6
50	1
5.0	2
50.0	3

Rule for Adding and Subtracting Significant Figures

When measurements are added or subtracted, the number of decimal places in the final answer should equal the smallest number of decimal places of any term.

Examples:

42.3
-1.86
$----$
$40.44 \rightarrow 40.4$

1.4693
11.18
$+2.1062$
$------$
$14.7555 \rightarrow 14.76$

25.3
17.82
$+0.863$
$------$
$43.983 \rightarrow 44.0$

Rule for Multiplying/Dividing Significant Figures

When measurements are multiplied or divided, the number of significant figures in the final answer should be the same as the term with the lowest number of significant figures.

Examples:

1) A $= 13.2 \times 4.6 = 60.72 \approx 61$ (answer)

2) F $= 0.82 \times 1.335 = 1.0947 \approx 1.1$ (answer)

3) N $= 2.21 \div 34 = 0.065$ (answer)

4) $G = 754 \div 6.4 = 760.4 \approx 760$ (answer)
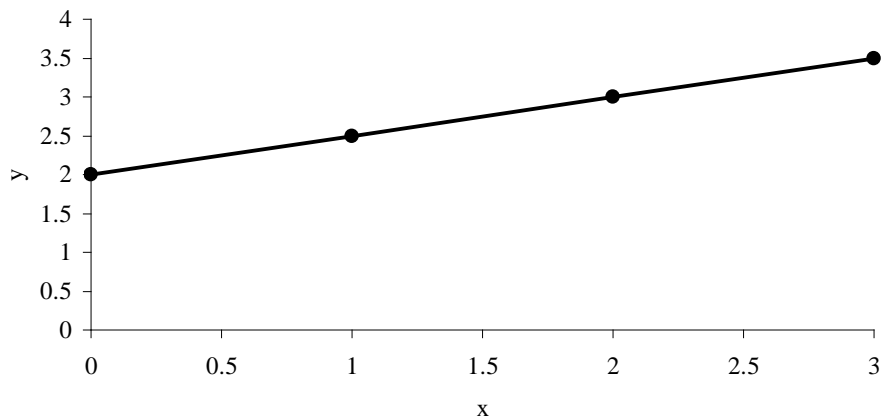
Lines

A linear equation is written in form:

$y(x) = m\,x + c$

where m and c represent the slope and the constant that basses y-axis, respectively. This equation can be sketch like the following graph:

The slope (m) can be evaluated by taking any two points on a line then use the relation

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

c is the intercept point with y-axis.

Example: write the straight line equation for above figure?

Mean Value

Suppose an experiment were repeated many, say N, times to get, x_1, x_2, x_3, ..., x_N. If the errors were random then the errors in these results would differ in sign and magnitude. So if the average or mean value of our measurements were calculated,

$$\bar{x} = \frac{x_1 + x_2 + ... + x_N}{N} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Some of the random variations could be expected to cancel out with others in the sum. This is the best that can be done to deal with random errors: repeat the measurement many times, varying as many "irrelevant" parameters as possible and use the average as the best estimate of the true value of x.

Example: Find the mean value for following data

3.2cm, 3.4cm, 3.0cm, 3.1cm, 3.5cm, 3.4cm.

Solution

$$\bar{x} = \frac{3.2+3.4+3.0+3.1+3.5+3.4}{6} = 3.3$$

Fractional error

The fractional error is the absolute value of the error divided by the accepted value (A).

Absolute value error (E) $= |\bar{x} - A|$

The fractional error $= \dfrac{|\bar{x} - A|}{A} = \dfrac{E}{A}$

The percent error $= \dfrac{E}{A} x\,100\%$

Example:-

In the lab experiment, group a found g = 10.1 m/s². If the accepted value of g = 9.8m/s². What is the fractional and percent error?

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Experiment # 1

Measurements

1.1 Purpose

The purpose of this lab experiment is to use the measurement tools like vernier caliper and micrometer to measure π and the volume of a small sphere.

1.2 Method

The circumference of a circular disk (C) is given by:-

$$C = \pi d \qquad\qquad\qquad 1.1$$

where C d is the diameter of circular disk.

By taking the ratio:

$$\pi = \frac{C}{d} \qquad\qquad\qquad 1.2$$

b- The volume of a small sphere (V) is given by:-

$$V = \frac{4}{3}\pi \left(\frac{d}{2}\right)^3 = \frac{2}{3}\pi d^3 \qquad\qquad\qquad 1.3$$

where d is the diameter of sphere.

1.3 Equipments:-

To do this experiment we want the following equipments:

Vernier caliper, micrometer, ruler, wooden disk, a small sphere, and paper tape.

1.4 Procedure:-

Part one: - Determine π value.

 a) Wrap the paper tape around the wooden disk and take the mark.

 b) Measure the length of marked tape by ruler.

 c) Measure the diameter of disk by vernier caliper, and repeat it three times.

 d) Evaluate the average value of the diameter and use equation 1.2 to evaluate π.

Part two: - Determine the volume of a small sphere.

 a) Measure the diameter of a small sphere by using a micromiter, and repeat it three times.

 b) Fill the table 2 to evaluate V from equation 1.3.

Experiment #1

Measurements

Name:………………………………… Registration number:………….

Section:…………… Date:……………… Mark:…………………………..

Results and Discussions

1- The aim …………………………………………………….............................

………………………………………………………………………………………

Part one:

1- Fill Table 1.

Number of trial	L (cm)	d (cm)
1		
2		
3		
4		
Mean value		

2- What is the measured value of π?

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3- What is the fractional and percentage error in π if the accepted value of $\pi = 3.14$?

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Part two:

1- Fill Table 2.

$\pi = $ …………

Number of trail	d (cm)
1	
2	
3	
Mean value	

2- Use equation 1.3 to evaluate the volume of sphere?

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………………………………………………………………………………………….

3- What are the sources of errors in the experiment?

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Experiment # 2

Vectors, Force Table

2.1 Purpose:-

The purpose of this lab experiment is to verify the parallelogram law of vector addition by using a force table.

2.2 Method:-

A vector is a quantity that possesses both magnitude and direction; examples of vector quantities are velocity, acceleration and force. A vector can be represented by an arrow pointing in the direction of the vector; the length of the line should be proportional to the magnitude of the vector.

Vectors can be added either graphically or analytically. The sum or resultant of two or more vectors is a single vector which produces the same effect. For example, if two or more forces act at a certain point, their resultant is that force which, if applied at that point, has the same effect as the two separate forces acting together. The equilibrant is defined as the force equal and opposite to the resultant. Suppose we have two vectors **A** and **B** with angle θ between them, as Fig. 2.1.
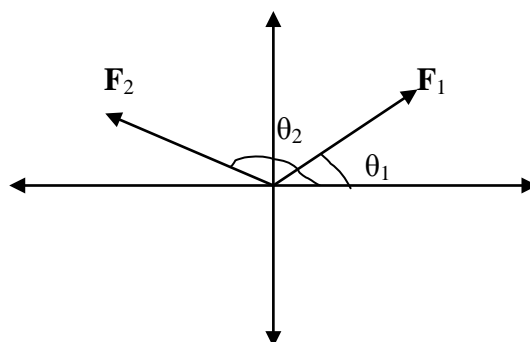
Fig. 2.1

The resultant of any two or more vectors can be measured by three methods:-

a) Graphical Method.

Two forces are added together by drawing them to scale using a ruler and protractor. The second force (F_2) is drawn with its tail to the head of the first force (F_1). The resultant (F_R) is drawn from the tail of F_1 to the head of F_2. See Fig. 2.2. Then the magnitude of the resultant can be measured directly from the diagram and converted to the proper force using the chosen scale. The angle can also be measured using the protractor.

Fig. 2.2

b) Component Method.

Two forces are added together by adding the x- and y-components of the forces. First the two forces are broken into their x- and y-components using trigonometry:

$F_{1x} = F_1 \cos\theta_1$ $\qquad$ $F_{1y} = F_2 \sin\theta_1$
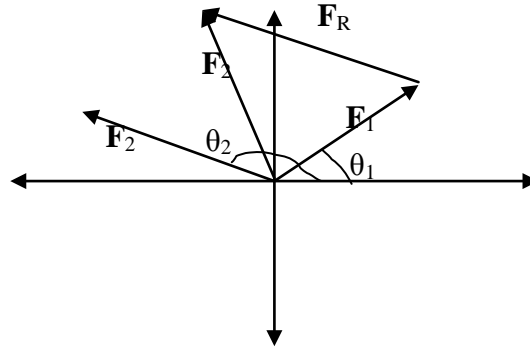
$F_{2x} = F_2 \cos\theta_2$ $\qquad$ $F_{2y} = F_2 \sin\theta_2$

where F_{ix} and F_{iy} are the component of vector $\mathbf{F}_i$ along x and y direction, respectively. To determine the sum of $\mathbf{F}_1$ and $\mathbf{F}_2$, the components are added to get the components of the resultant $\mathbf{F}_R$:

$F_{Rx} = F_1 \cos\theta_1 + F_2 \cos\theta_2$

$F_{Ry} = F_1 \sin\theta_1 + F_2 \sin\theta_2$

To complete the analysis, the resultant force must be in the form of a magnitude and a direction (angle). So the components of the resultant (F_{Rx} and F_{Ry}) must be combined using the Pythagorean Theorem since the components are at right angles to each other:

$$F_R = \sqrt{(F_{Rx})^2 + (F_{Ry})^2}$$

$$\theta = \tan^{-1} \frac{F_{Ry}}{F_{Rx}}$$

where θ is the angle enclosed by F_R and positive x-axis as revolve counter clock wise.

c) Experimental Method.

Two forces are applied on the force table by hanging masses over pulleys positioned at certain angles. Then the angle and mass hung over a third pulley are adjusted until it balances the other two forces. This third force is called the equilibrant ($\mathbf{F}_E$) since it is the force which establishes equilibrium. The equilibrant is not the same as the resultant ($\mathbf{F}_R$). The resultant is the addition of the two forces. While the

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equilibrant is equal in magnitude to the resultant, it is in the opposite direction because it balances the resultant (see Figure 2.3). So the equilibrant is the negative of the resultant.
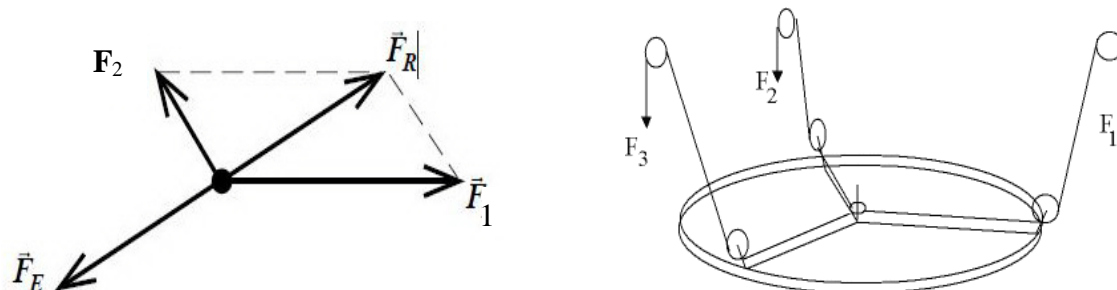

Fig. 2.3 A schematic diagram of a force table

2.3 Equipments:-

You will use the following equipments to examine various vector forces in equilibrium

Force Table, three pulleys and pulley clamps, three mass hangers, mass set, string, metric ruler, protractor, and one sheet paper.

2.4 Procedure:-

To find the resultant of two forces: a 100g force at 30^0 and a 200g force at 155^0.

   a. Place one pulley at 30^0 and the other at 155^0.

   b. On each string that runs over these pulleys, place a mass of 100g at 30^0 and 200g at 155^0 (including hanger - each hanger has a mass of 50g).

   c. With a third pulley and masses, balance the forces exerted by the two masses. The forces are balanced when the ring is centered on the central metal peg. To balance the forces, move the third pulley around to find the direction of the balancing force, and then add masses to the third hanger until the ring is centered.

   d. The balancing force obtained in (c) is the equilibrant force. The resultant has the same magnitude as the equilibrant but opposite direction. To determine the direction of the resultant, subtract 180 degrees from the direction of the equilibrant.

   e. Include a graph where you obtain the equilibrant vector using the graphical method. Make sure to label and include direction/magnitude labels and values of each given vector on your graph. When reading your graphical method, the reader ought to be able to see clearly: the two vectors given with their

respective angles, and the equilibrant vector with its angle. Finally, include the scale that you chose.

f. Express each given vector in component notation, add them up and calculate the resultant vector. From your result, express the resultant vector in magnitude and direction. Finally, deduce the equilibrant vector (in magnitude and direction).

Experiment #2

Vectors, Force Table

Name:………………………………………… Registration number:………….

Section:…………… Date:………………… Mark:…………………………..

Results and Discussions:-

1- The aim:...

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2- What is the magnitude and direction of the equilibrant force that you found by

force table?

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3- What is the magnitude and direction of the resultant force that you found by

force table?

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4- Find the magnitude and the direction of the resultant force by using graphical

method?

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5- Find the magnitude and the direction of the resultant force by using component

method?

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Experiment # 3

Air Track

3.1 Purpose:-

The purpose of this lab experiment is to study the motion in one dimension of a glider on an air track**.**

3.2 Theory:-

A glider moves with very little friction on an air track. If set in motion on a level track it therefore moves with nearly constant velocity. We can make the glider accelerate by applying a force on the glider. This will be done by attaching a string to the glider, passing the string over an air pulley at one end of the track, and attaching small slotted weights to the free end, as seen in Figure 1.
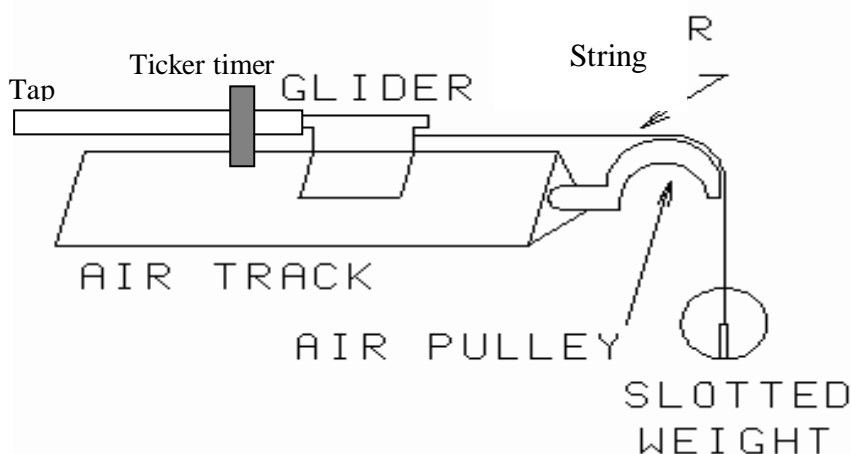
Fig. 1. Accelerating a glider on a level air track

The hanging weight must be small compared to the glider's weight. We want to keep the glider velocity very small at all times. The 50 gm weight hangers should not be used, for that much weight would produce too much acceleration. Attach slotted weights directly to the end of the string.

Connect a paper tape in the end of a glider in opposite side of motion and put the tape in the ticker timer device. The frequency of the ticker timer device is 50 Hz, so each five dots take 0.1 second.

Let the glider moves when the ticker timer on. You will get the ticker tape as Figure 2.

Fig. 2 A scheme of ticker timer tape.

Use the equation of motion in one dimension.

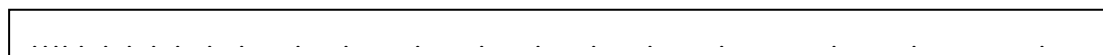$\Delta x = x_f - x_i$

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} \qquad\qquad 3.1$$

$$v = \frac{dx}{dt}$$

$$a_{avg} = \frac{\Delta v}{\Delta t} \qquad\qquad 3.2$$

$$a = \frac{dv}{dt} \qquad\qquad 3.3$$

Where Δx is the displacement, v_{avg} and v are the average and instantaneous velocity, respectively. a_{avg} and a is average and instantaneous acceleration, respectively.

3.3 Equipments:-

To do this experiment we want the following equipments:

Air track, air pump, a glider, hunger mass, metric ruler, pulley, string, ticker timer device, and ticker timer tape.

3.4 Procedure:-

a) Set a glider and all devices as Figure 1.

b) Switch on the air pump and ticker timer device.

c) Let a glider to accelerate.

d) Analyzing the ticker timer tape.

e) Find the average velocity and acceleration.

Experiment # 3

Air Track

Results and Discussions:-

1- The aim:..

....

2- Fill the Table

t (sec.)	x_i (cm)	x_f (cm)	Δx (cm)	v_{avg} (cm/s)	Δv (cm/s)	a_{avg} (cm/s^2)
0	0	0				
0.05						
0.1	0					
0.15						
0.2						
0.25						
0.3						
0.35						
0.4						
0.45						
0.5						

3- Graph x_f versus time t, then find instantaneous velocity at t = 0.35sec.

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……………………………………………………………………………………………

4- Graph v_{avg} versus time t, and then find the slope?

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5- Find the acceleration a from Q4?

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Experiment # 4

Projectile Motion

4.1 Purpose:-

The purpose of this lab experiment is to determine the initial velocity of a projectile.

4.2 Method:-

Projectile motion is the motion of a particle that is launched with an initial velocity v_i making angle θ with the horizontal and having the free-fall acceleration g. The horizontal and the vertical motions of the projectiles are independent of each other. The horizontal motion represents a uniform motion (no acceleration) while the vertical motion is a free fall motion.

A projectile is being fired from an origin ($x_i=0$) with the initial velocity v_i at angle θ with positive x-axis, as shown in Fig.1. The components of v_i in x and y-axis are

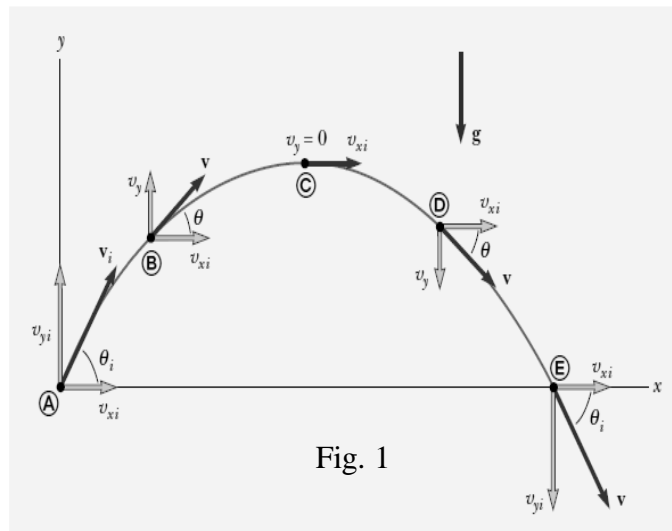$v_{ix} = v_i \cos\theta$ 4.1-a

$v_{iy} = v_i \sin\theta$ 4.1-b

Fig. 1

The velocity vector (**v**) at a certain time t is

$\mathbf{v} = \mathbf{v_i} + \mathbf{a}\,t$ 4.2-a

In the vector component form, the equation 2 become

$\mathbf{v} = (v_{xi}\,\mathbf{i} + v_{yi}\,\mathbf{j}) - gt\,\mathbf{j} = (v_i \cos\theta)\mathbf{i} + (v_i \sin\theta - gt)\mathbf{j}$ 4.2-b

since $a_x = 0$, and $a_y = -g$

The horizontal velocity (v_x) and vertical velocity at a certain time is

$v_x = v_{xi} = v_i \cos\theta$ 4.3-a

$v_y = v_{yi} - g\,t = v_i \sin\theta - g\,t$ 4.3-b

The horizontal distance of the particle at any time t is

$x_f = v_{xi}\,t = (v_i \cos\theta)\,t$ 4.4-a

On the other hand, the vertical position of the particle at any time t is

$$y_f = v_{yi} - \frac{1}{2}gt^2 = v_i \sin\theta - \frac{1}{2}gt^2 \qquad\qquad \text{4.4-b}$$

When the particle reaches its maximum height (h) at A, as shown in Fig.2, its velocity becomes zero. Therefore, from the equation 4.3-b, the time (t_A) needed to reach maximum height is:

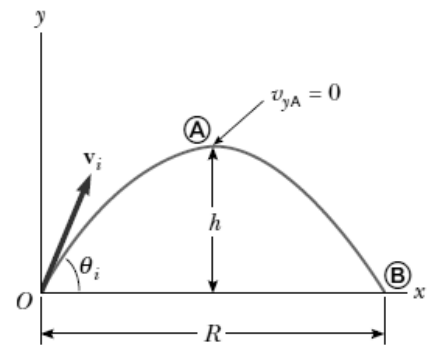$$0 = v_i \sin\theta - gt_A$$

$$t_A = \frac{v_i \sin\theta}{g} \qquad\qquad \text{4.5}$$

Fig. 2

The maximum height (h) can be found by substituting equation 4.5 in equation 4.4-b

$$h = \frac{v_i^2 \sin^2\theta}{2g} \qquad\qquad \text{4.6}$$

In the case of $\theta = 90^\circ$, we have

$$h = \left(\frac{v_o^2}{2g}\right)$$

This result agrees with the maximum height of a ball thrown vertically upward.

In the case of $\theta = 45^\circ$, we have a maximum value for h

$$h = \left(\frac{v_o^2}{4g}\right)$$

In the case of $\theta = 0^\circ$, we have no height

$$h = 0$$

The Range, R of the projectile is defined as the maximum distance traveled along the x-axis.

$$R = \frac{v_i^2 \sin 2\theta}{g} \qquad\qquad \text{4.7}$$

In the case of $\theta = 90^\circ$, we have no horizontal distance

$$R = 0$$

In the case of $\theta = 45^\circ$, we have a maximum range

$$R = \left(\frac{v_o^2}{g}\right)$$

The initial velocity can be found by using equation 4.7:

$$v = \sqrt{\frac{Rg}{\sin 2\theta}} = \sqrt{\frac{g}{Slope}} \qquad\qquad 4.8$$

Where the $slope = \dfrac{\Delta R}{\Delta \sin 2\theta}$

4.3 **Equipments**:-

To do this experiment we want the following equipments:

The large projection apparatus, meter stick, iron ball, spirit level, and clamp

4.4 Procedure:

1. Keep the apparatus on a horizontal floor.

2. load the gun with the ball and fire it into the floor, the ball moving as a projectile, strikes the ground at a certain horizontal distance x. Note it and measure the horizontal distance twice more and take x average.

3. Change the tension (the angle of the gun) to three more values and repeat the above steps.

4. Plot (sin2θ) on x-axis against the average value of the horizontal distance x for each angle.

5. Draw a straight line through these points and find the slope.

Experiment # 4

Projectile Motion

Name:………………………………… Registration number:………….

Section:…………… Date:……………… Mark:……………………….

Results and Discussions

1- The aim …………………………………………………….............................

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2- Fill the Table

θ (in degree)	R (m)	Sin2θ

3- Draw the range (R) versus sin2θ and find the slope.

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4- Evaluate initial velocity of the ball?

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5- What is the maximum height for the ball when $\theta = 60^0$?

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6- What are the sources of errors in this experiment?

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Experiment # 5

Newton's Law

5.1 Purpose:-

The purpose of this lab experiment is to verify Newton's Second Law by investigation of acceleration as a function of the total mass of the system.

5.2 Method:-

In this experiment we verified Newton's Second Law by measuring the acceleration of a system subject to a net external force. Newton's second law states that the acceleration **a** of an object is directly proportional to the net force acting on the object and inversely proportional to the object's mass m. Newton's second law can be expressed as an equation using

$\mathbf{F} = \mathrm{m}\,\mathbf{a}$

The unbalanced force was supplied by a mass falling in the earth's gravitational field as is shown in Figure 1. Mass m rested on a smooth horizontal air track and was attached to mass M by a light string passing over a frictionless pulley. When the system was released m was pulled along the track by the force supplied by the suspended mass M. The air track and pulley had small openings through which jets of air were ejected to create a nearly frictionless surface. The mass m will move through two photo gates to measure the time, velocity and acceleration needed to cover the displacement.
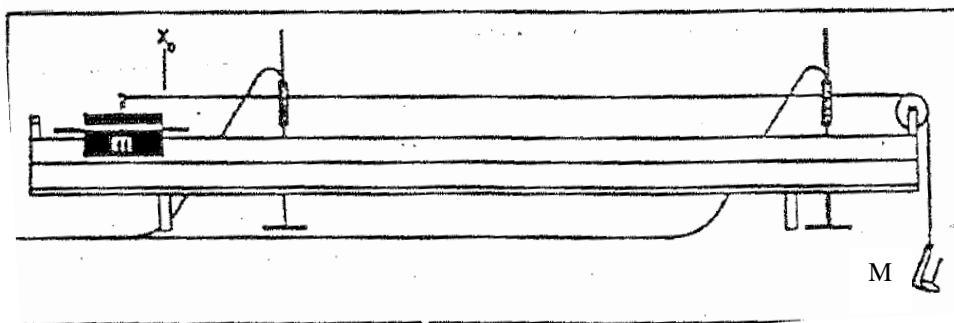

Fig. 1 A scheme of the air track

We can use the following equation to measure acceleration:

$$v = \frac{\Delta x}{\Delta t}$$

$$a = \frac{\Delta v}{\Delta t}$$

5.1

Newton's second law was applied to *M* and *m*. The resulting system of equations were solved to eliminate the tension in the string yielding

$$a = \frac{M}{M+m} g \qquad\qquad 5.2$$

If we kept the total mass of the system (M+m) is constant and varying the hanging mass (M) by remove a set of mass from it to added it to the m. We will get the different acceleration. The graph drown as a versus M and evaluate the slope of liner relation will help to find g.

$g = (M + m)$ slope $\qquad\qquad 5.3$

5.3 Equipments:-

To do this experiment we want the following equipments:

Air track, air pump, mass pan, various slotted masses, balance, a glider, photogates, and stop watch, metric ruler.

5.4 Procedure:-

a) Weight the glider by balance, and set a glider and all devices as Figure 1.

b) Measure the distance that a glider will move through a photogate.

c) Let a glider to accelerate and measure the total time (t).

d) Evaluate a by using a = (Δv/ t).

e) Remove 10g from hanger mass and put it on a glider then repeat step c.

f) Repeat step e another 2 times.

Experiment # 5

Newton's Law

Results and Discussions:-

1- The aim:...

....

2- Fill the following table

m +M = …………g   x = ………..cm

M (g)	t_1 (sec.)	v_1 (cm/s)	t_2 (sec.)	v_2 (cm/s)	Δv (cm/s)	t (sec.)	a_1 (cm/s^2)

3- Graph a linear relation a versus M, and find the slope?

………………………………………………………………………………

………………………………………………………………………………

4- Evaluate the acceleration due to the gravity g.

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………………………………………………………………………………..

5- If the accepted value of g = 980 cm/s^2, evaluate the percent error of g?

………………………………………………………………………………

………………………………………………………………………………

Experiment # 6

Coefficient of Static Friction

6.1 Purpose:-

The purpose of this lab experiment is to measure the static coefficient of friction (μ_s) between a wooden block and a wooden surface by measuring its inclination.

6.2 Method:-

Friction is the force that resists the relative motion of one surface in contact with another. There are two types of friction: static and kinetic. Usually, the kinetic frictional force is less than the maximum value of the static frictional force. The static frictional force is given by

$$f_s = \mu_s N \qquad\qquad 6.1$$

where μ_s is the coefficient of static friction, and N is the normal force. Figure 6.1 show a wooden block on the inclined ramp at angle θ which a wooden block just starts to slide down.

Fig. 6.1 Scheme graph of a wooden block on include ramp
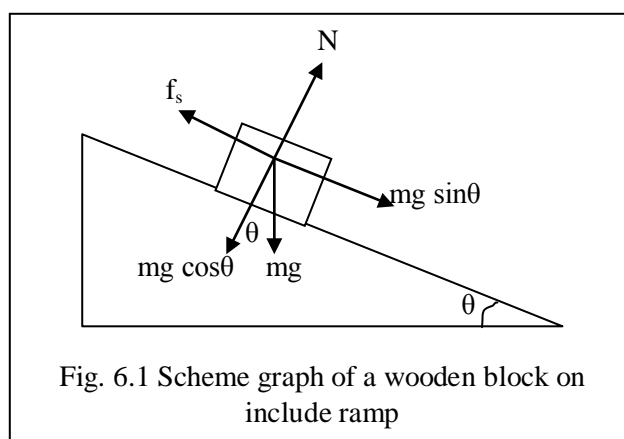
The weight of a wooden block (mg) on the inclined surface by θ can be divided into components in perpendicular directions. At equilibrium, the compenent of resultant force equal zero.

$$f_s = mg\ \sin\theta \qquad\qquad 6.2\text{-a}$$

$$N = mg\ \cos\theta \qquad\qquad 6.2\text{-b}$$

Substitute equation 6.2-b in equation 6.1

$$f_s = \mu_s\ mg\ \cos\theta \qquad\qquad 6.3$$

Substitute f_s of equation 6.3 equation 6.2-a, we get

$$\mu_s\ mg\ \cos\theta = mg\ \sin\theta$$

$$\mu_s = \tan\theta \qquad\qquad 6.4$$

In this experiment, the angle of repose method will also be used to determine the coefficient of static friction. The frictional force between a wooden block and the wooden inclined surface will be measured.

6.3 Equipments:-

To do this experiment we want the following equipments:

A wooden block, a flat board to be used as a ramp, balance, and protractor.

6.4 Procedure:-

a) Weight a wooden block the put in on a horizontal surface.

b) Raise the surface from one side slowly until a wooden block be come slide.

c) Measure the angle θ and repeat step b two times.

d) Evaluate the mean value of θ and used it to measure μ_s and f_s.

Experiment # 6

Coefficient of Static Friction

Name:………………………………………… Registration number:…………..

Section:…………… Date:………………… Mark:…………………………..

Results and Discussions

1- The aim:………………………………………………………………………………

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2- What are the mass of a wooden block, and the mean value of θ?

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

3- Find the coefficient of static friction (μ_s) between the surface and the block, and then evaluate friction force?

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4- What are the factors that the coefficient of static friction depends on?

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Experiment # 7

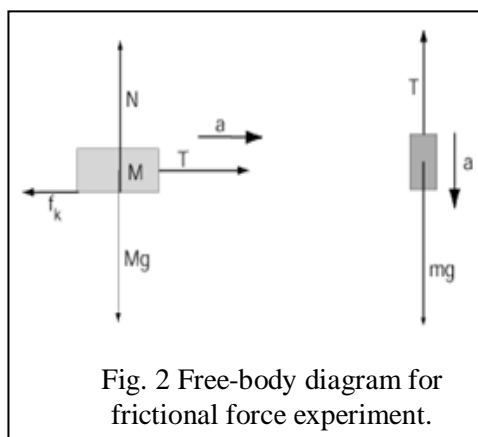# Coefficient of Kinetic Friction

7.1 Purpose:-

The purpose of this lab experiment is to determine the coefficient of kinetic friction between the wooden block and the table.

7.2 Method:-

Consider the system shown in Figure 1. A block of mass *M* is placed on a level table and connected to a mass *m* by a light string running through a pulley. If mass *m* is released, it will start to fall and the wooden block will be pulled across the table. A free body diagram of this system is shown in Figure 2.

Fig. 1 A schematic diagram of the experiment
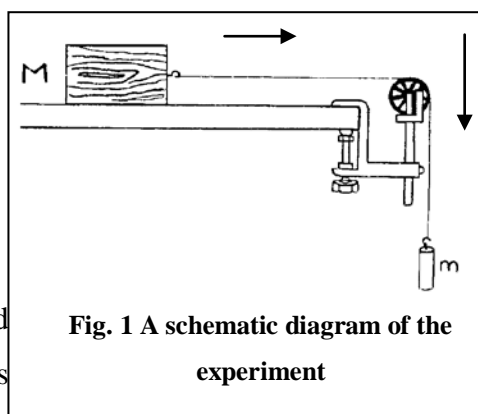
We begin our analysis of this system by writing equations to resolve forces in the x and y directions. Notice that the pulley in Figure 1 has the effect of redirecting the force labeled as T on M from the horizontal direction (along the + x axis) to the vertical direction (positive y axis) on m.

Fig. 2 Free-body diagram for frictional force experiment.

Added mass m on mass hanger until the system moves with constant velocity. Since the cart does not accelerate,

v = constant

$a = 0, \quad \sum F = 0$

For mass M:

$T - f_k = 0 \rightarrow \quad T = f_k = \mu_k N$

$N = Mg$

$T = \mu_k Mg$ $\qquad\qquad\qquad$ 7.1

Where μ_k is the coefficient kinetic friction, N is normal force, and f_k is the kinetic friction force.

For mass m:

$T = mg$ 7.2

Substitute equation 7.1 in equation 7.2, we get

$\mu_k\, Mg = mg$

$$\mu_k = \frac{m}{M}$$ 7.3

7.3 Equipments:-

         To do this experiment we want the following equipments:

A frictional horizontal surface, a wooden block, string, pulley, mass hangers, balance, and mass set.

7.4 Procedure:-

a) Set a wooden block and horizontal surface as Figure 1.

b) By adjusting m (the mass on hanger) find the mass which just moves the wooden block (M) along the horizontal surface at constant velocity.

c) Increase the mass of block by 100g and again find the mass m.

d) Repeat step b three times again by adding 150g and find m for each step.

e) Plot the graph between m versus M.

f) Find the slope to evaluate μ_k.

Experiment # 7

Coefficient of Kinetic Friction

Results and Discussions:-

1- The aim:..

....

2- Fill the Table

M (g)	m (g)
100	
250	
400	
550	

3- Plot M versus m, and then find the slope?

……………………………………………………………………………………

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4- Evaluate μ_k?

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5- What are the sources of error?

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Experiment # 8

Uniform Circular Motion

8.1 Purpose:-

The purpose of this lab experiment is to examine the relationship between mass, velocity, radius, and centripetal force.

8.2 Method:-

An object of mass m that moves in a circle at constant speed (v) in radius (r) is said to undergo uniform circular motion, as shown in Figure 1. Examples are a ball on the end of a string revolved around one's head. Because the mass on the end of the string is always changing direction, the velocity of the mass is always changing (remember that velocity is a vector quantity), and therefore the mass is accelerating. The velocity of the mass is always changing direction toward the center of the circle. It follows then that the mass is always accelerating toward the center of the circle. The centripetal acceleration (a_r) given by:

$$a_r = \frac{v^2}{r} \qquad\qquad 8.1$$

The centripetal force (F_r) that acts on a mass is

$$F_r = ma_r = \frac{mv^2}{r} \qquad\qquad 8.2$$

If the system is connected as Fig. 2
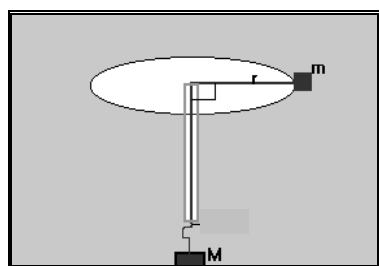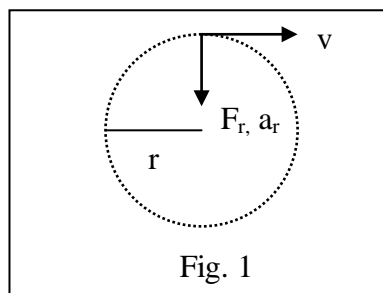

Fig. 1

Fig. 2

The tension (T) of string gives by:

$$T = F_r = Mg \qquad\qquad\qquad\qquad 8.3$$

Where M is hanging mass.

By subtract equation 2 in equation 3, we get

$$T = F_r = Mg = \frac{mv^2}{r} \qquad\qquad\qquad\qquad 8.4$$

31

The constant speed covers the circumference of one circular bath in period τ

$$v = \frac{2\pi r}{\tau}$$ 8.5

The frequency (f) is the number of revolves of a repeating event per unit time (t).

$$f = \frac{total \ number \ of \ revolves}{total \ time} = \frac{1}{T}$$ 8.6

Where T is the period.

Substitute equation 8.6 in equation 8.2, we get

$$v = 2 \pi r f$$ 8.7

and the revolved mass is

$$m = \frac{F_r}{4\pi^2 r f^2}$$ 8.8

8.3 Equipments:-

To do this experiment we want the following equipments:

A rubber mass, a mass hunger, mass set, a string 1 to 1.5 meters long, a glass pipe, stopwatch, metric ruler, balance, and clips.

8.4 Procedure:-

a) Tie a clip at the end of your string that will act as a stop and r =20cm. It is important to make a good stop so that your masses do not fly off when you start swinging your string.

b) To calculate velocity, use your stopwatch and the equation 8.7. Remember that to calculate velocity you don't need to time just one revolution. In fact, it would be smart to time 10 revolutions to find your velocity.

c) Add 20 g on the mass hunger, and then repeat step b.

d) Fill the table and graph F_r versus f^2 then find the slope.

Experiment # 8

Uniform Circular Motion

Name:………………………………………… Registration number:………….

Section:…………… Date:………………… Mark:……………………………

Results and Discussions:-

1- The aim:..

....

2- Fill the Table

r = 20cm   number of revolve = 10   g = 980cm/sec^2

M (gm)	F$_r$ (dyne)	f (sec^{-1})	f^2 (sec^{-2})

3- Plot a linear relation between F$_r$ versus f^2. Find the slope?

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4- Use equation 8.8 and the slope to find mass m?

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5- Use the balance to measure the mass m.

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6- Evaluate the percent error of the mass m?

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7. What are the sources of error in this experiment?

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Experiment # 9

Hooke's Law

9.1 Purpose:-

      The purpose of this lab experiment is to study the behavior of springs in static situations. We will determine the spring constant, k, for an individual spring using Hooke's Law.

9.2 Method:-

      If an applied force varies linearly with position, the force can be defined as $\mathbf{F} = k\,\mathbf{x}$ where k is called the force constant. Once such physical system where this force exists is with common helical spring acting on a body. If the spring is stretched or compressed a small distance from its equilibrium position, the spring will exert a force on the body given by Hooke's Law, namely

$$\mathbf{F_s} = -\,k\,\mathbf{x} \qquad\qquad\qquad 9.1$$

where $\mathbf{F_s}$ is known as the spring force. Here the constant of proportionality, k, is the known as the spring constant, and $\mathbf{x}$ is the displacement of the body from its equilibrium position (at $\mathbf{x} = 0$). The spring constant is an indication of the spring's stiffness. A large value for k indicates that the spring is stiff. A low value for k means the spring is soft.

The negative sign in Equation 1 indicates that the direction of $\mathbf{F_s}$ is always opposite the direction of the displacement. This implies that the spring force is a restoring force. In other words, the spring force always acts to restore, or return, the body to the equilibrium position regardless of the direction of the displacement.

When a mass, m, is suspended from a spring and the system is allowed to reach equilibrium, as shown in Figure 1, Newton's Second Law tells us that the magnitude of the spring force equals the weight of the body,

Fig. 1

$$\mathbf{F_s} = m\,\mathbf{g} \qquad\qquad\qquad 9.2$$

Therefore, if we know the mass of a body at equilibrium, we can determine the spring force acting on the body.

Equation 1 applies to springs that are initially unstretched. When the body undergoes an arbitrary displacement from some initial position, $\mathbf{x_i}$, to some final position, $\mathbf{x_f}$, this equation can be written as:
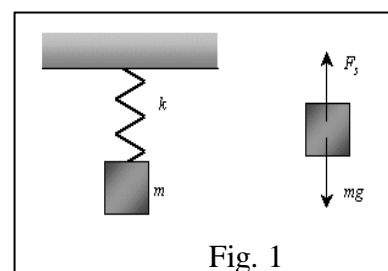
$\mathbf{F_s} = - k \, \Delta\mathbf{x}$ 9.3

where $\Delta\mathbf{x}$ is the body's displacement. By using equations 9.2 and 9.3 we can determine the force constant k as:

$k = (m/\Delta x) \, g$

If we draw a linear relation as Δx versus m and find the slope, we can evaluate k as:

$k = g/(slope)$ 9.4

9.3 Equipments:-

To do this experiment we want the following equipments:

A common helical spring, support stand, hook, mass pan, various slotted masses, and metric ruler.

9.4 Procedure:-

a) Hung the helical spring on the support stand with a hook and read the displacement.

b) Add the masses to the hook gradually. Begin from 20g and increase it continuously.

c) Take the read of the change of displacement Δx.

d) Fill the result in table.

e) Plot Δx versus m as a linear relation.

f) Find the slope then used the equation 9.4 to measure the force constant of spring.

Experiment #9

Hooke's Law

Name:………………………………… Registration number:…………..

Section:…………… Date:………………… Mark:…………………………..

Results and Discussions

1- The aim:………………………………………………………………………………

………………………………………………………………………………………………

2- Fill the table

m (g)	Δx (cm)
20	
35	
50	
60	

3- Plot Δx versus m and find the slope.

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4- What is the kind of the relation between m and Δx?

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………………………………………………………………………………………………

5- Find the force constant of spring *k*?

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6- What are the sources of error?

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Experiment # 10

Simple Pendulum

10.1 Purpose:-

The purpose of this lab experiment is to determine the acceleration due to gravity using the theory, results, and analysis of this experiment.

10.2 Method:-

A simple pendulum can be approximated by a small metal sphere which has a small radius and a large mass when compared relatively to the length and mass of the light string from which it is suspended, as shown in Figure 1.

If a pendulum is set in motion so that is swings back and forth, its motion will be periodic. The time that it takes to make one complete oscillation is defined as the period T, that given by:
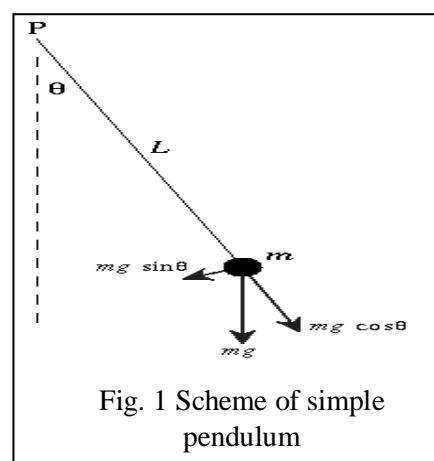

Fig. 1 Scheme of simple pendulum

$$T = t / n \qquad\qquad 10.1$$

where t is total time in second and n is the total number of oscillation. When a simple pendulum is displaced from its equilibrium position, there will be a restoring force that moves the pendulum back towards its equilibrium position. As the motion of the pendulum carries it past the equilibrium position, the restoring force changes its direction so that it is still directed towards the equilibrium position. The simple pendulum must be displaced with a small angle (why?) before swing. The simple pendulum motion is described by simple harmonic motion with period T given by:

$$T = 2\pi \sqrt{\frac{L}{g}} \qquad\qquad 10.2$$

where $\pi = 3.14$, L is the length of string, and g is the acceleration due to gravity.
The acceleration due to gravity g can be measured by:

$$g = 4\pi^2 \frac{L}{T^2} \qquad\qquad 10.3$$

10.3 Equipments:-

To do this experiment we want the following equipments:
The simple pendulum, metric ruler, support stand, and stop watch.

10.4 Procedure:-

a) Displaced the small sphere of the simple pendulum of length L_1 by a small angle and let it to oscillate.

b) Measure the time needed to complete 10 oscillations.

c) Repeat the step b by changing the length of string and fill Table 1.

d) Plot T^2 versus L and find the slope.

e) Evaluate g.

Experiment #10

Simple Pendulum

Name:…………………………………… Registration number:…………..

Section:…………… Date:………………… Mark:…………………………..

Results and Discussions:-

1) The aim ………………………………………………………………………..

…………………………………………………………………………………………

2) Fill the following table.

L(cm)	t (s)	T (s	T^2 (s^2)
10			
20			
30			
40			
50			
60			
70			

3) Plot T^2 versus L and find the slope

…………………………………………………………………………………………

…………………………………………………………………………………………

4) What is the relation between T^2 and L?

…………………………………………………………………………………………

5) Evaluate g from graph

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6) Why θ must be smaller than 15^0?

…………………………………………………………………………………………

7) What are the sources of errors in this experiment?

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8) Evaluate the percentage error in g if accepted value is g = 980 cm/s^2?

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