Palestine Technical University-Khadoorie

LABORATORY MANUAL

General Physics Lab I

Prepared by

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2019

Introduction

MEASUREMENTS AND UNCERTAINTIES

OBJECTIVES:

- **To be familiar with some measuring tools and principles.**
- **To determine errors of some measured quantities.**

EQUIPMENT:

1. **Micrometer.**
2. **Vernier caliper.**
3. **Strip (or paper tape).**
4. **Solid cylinder (or rod).**
5. **Balance**
6. **Five wooden discs.**

INTRODUCTION:

The equation of a straight line passing through the origin (x=0, y=0) is given by:

$$y = ax$$

Where, a is the slope of the line, x is the independent variable and y is the dependent variable. For any round object the circumference c is directly proportional to its diameter d, or:

$$c \propto d$$

And

$$c = \pi d$$

Where π is a constant. By measuring the values of c and d of many round objects and plotting c versus d, one can determine the value of from the slope. In addition, you shall determine the density of some materials (copper, wood and steel). The density of any material is defined as the ratio of the mass (m) of an object to its volume. For a cylinder of length L and diameter d, the volume v is determined from the relation:

$$V = \pi L(\frac{d}{2})^2 \tag{1}$$

Therefore, the relation gives the density of the cylinder:

$$\rho = \frac{m}{V} = \frac{4m}{\pi L d^2} \tag{2}$$

In this experiment you shall learn how to use some measuring instruments to measure dimensions, and use these measurements to calculate some constants. In addition, you shall learn how to express errors in terms of standard deviation, combined error, and percentage error. You shall use meter ruler, vernier caliper, and a micrometer to measure the dimensions and a balance to measure the masses. The Figures.1 and 2 show how to read the vernier caliper.

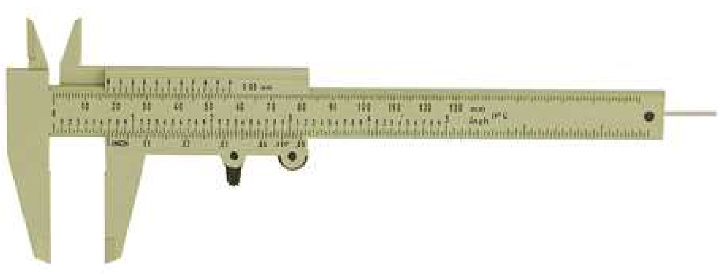
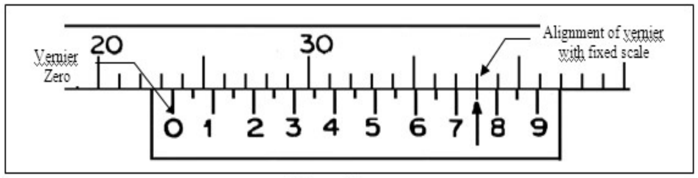


Figure 1:



Reading =23.75 mm Figure.2

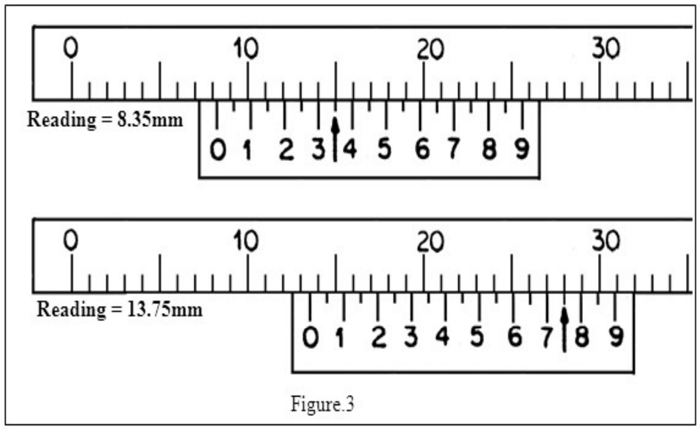


Figure 2:

The Figure 3 show how to read the micrometer.

Experimental Procedure: You should be careful when taking any of the measurements to keep errors as small as possible. This means that you should never be satisfied with a single measurement, since taking the average of many measurements minimizes errors.

Part (1): Determination of π:

1. **Measure the circumference of the given round objects by using the paper strip and the meter ruler.**

2. **Use the vernier caliper to measure their diameters. Record your measurements in Table-1.**

Part (2): Determination of Density:

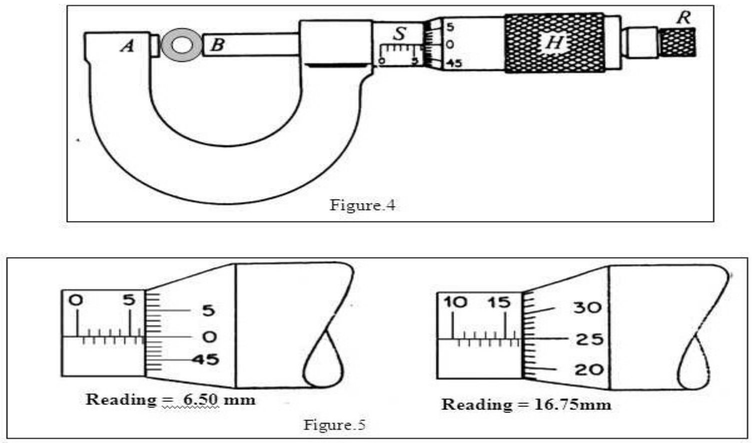


Figure 3:

1. **Choose one of the cylinders(metal, wood or copper)**
2. **Measure the mass by using the balance.**
3. **Measure the length by using the vernier caliper.**
4. **Measure the diameter using the micrometer.**

Record your measurements in Part 2.

Name: **Grade:**

Students No.: **Date:**

Data and Calculation

N.	**Circumference c(cm)**	**Diameter d(cm)**	$\pi = \frac{c}{d}$	**Deviation** $d_i = \pi - \overline{\pi}$	(d_i^2)
1					
2					
3					
4					
5					
	Mean value $\overline{\pi}$**=**	**...........**		$\sum(d_i^2) =$	**.........**

Part 1: Determination of π**:**

1. **Calculate the value of for each measurement of c and d.**

2. **Calculate the mean value.**

3. **Calculate the deviation of each from the mean** $d_i = \pi - \overline{\pi}$

4. **Calculate the sum of** d_i^2 **where** $\sum(d_i)^2$**.**

5. **Tabulate your results in Table** (1)**.**

6. **Calculate the error of the mean** $\Delta\overline{\pi}$ **given that:**

$$\Delta\overline{\pi} = \sqrt{\frac{1}{N(N-1)}\Sigma_{i=1}^{N}(d_i^2)} \tag{3}$$

7. **Plot the graph between c and d. Calculate the slope of the graph.**

8. **What does the slope here represent?**

   ..

9. **Calculate the percentage error in π that you found ,given that the real value of π = 3.143 Percentage error of π =**

Part 2 : determination of density: The density of a rod:

1. **Tabulate your measurements**

   (a) $M \pm \triangle M =$

   (b) $L \pm \triangle L =$

   (c) $d \pm \triangle d =$

   where $\triangle M$,$\triangle L$ and $\triangle d$ are the instrumental errors.

2. **Calculate the density of the rod using Eqn. (2).**

3. **Calculate the error $\triangle \rho =$**

4. **Derive the unit of the density.**

Experimental No. (1)

Vectors

Objective:

To determine the resultant of two or more forces by different techniques and to compare it with their equilibrant force.

Apparatus:

Vector force table, Weight hangers, weights, pulleys and protractor.

theory:

vector quantities are physical quantities which have magnitude and direction. Suppose we have two forces $\overrightarrow{F}_1$ and $\overrightarrow{F}_2$ acting on an object as shown in Fig.(14), We can replace the forces $\overrightarrow{F}_1$ and $\overrightarrow{F}_2$ by a single force $\overrightarrow{R}$ called the resultant force which has the same effect as the two forces.

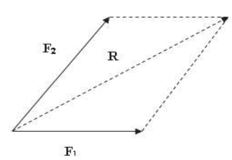


Figure 4:

$$\overrightarrow{R} = \overrightarrow{F}_1 + \overrightarrow{F}_2 \tag{4}$$

The resultant forces can be found by different methods.

1. **Graphically (Polygon rule): In this method all forces should be represented by rows in head-to-tail fashion. Consider the forces $\overrightarrow{F}_1$, $\overrightarrow{F}_2$ and $\overrightarrow{F}_3$. The vector $\overrightarrow{R}$ which closes the diagram is the**

result force. The length of each arrow should represent the magnitude of the corresponding forces, see Fig.(5). This is done by

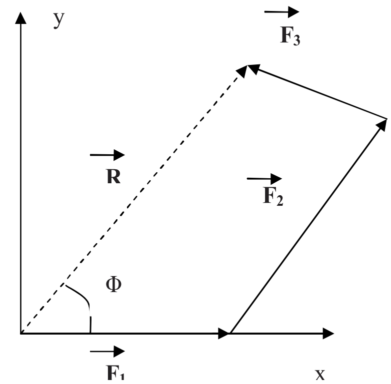


Figure 5:

choosing a suitable scale. The angle θ represents the direction of $\overrightarrow{R}$ with respect to $\overrightarrow{F}_1$. If two forces instead of three forces or more are applied, the above method is called triangle method.

2. **Component rule: In this method each force is resolved into its horizontal and vertical components:**

$$F_x = |\overrightarrow{F}| \cos\theta \tag{5}$$

$$F_y = |\overrightarrow{F}| \sin\theta \tag{6}$$

Where, θ is the angle between $\overrightarrow{F}$ and the positive x-axis, as shown in fig.(3). Therefore:

$$F_x = \sum_{i=1}^{N} F_i \cos\theta_i \tag{7}$$

$$F_y = \sum_{i=1}^{N} F_i \sin\theta_i \tag{8}$$

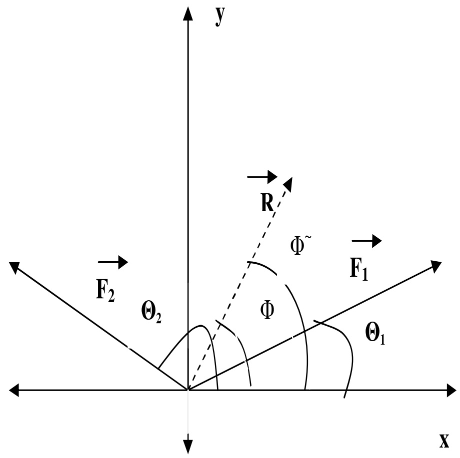


Figure 6:

the magnitude of $\overrightarrow{R}$ is given by:

$$|\overrightarrow{R}| = \sqrt{F_x^2 + F_y^2} \tag{9}$$

and its direction:

$$\phi = \tan^{-1} \frac{F_y}{F_x} \tag{10}$$

3. **Calculation: For two forces $\overrightarrow{F}_1$ and $\overrightarrow{F}_2$, the magnitude of $\overrightarrow{R}$ is:**

$$|\overrightarrow{R}| = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta} \tag{11}$$

where, θ is the angle between $\overrightarrow{F}_1$ and $\overrightarrow{F}_2$. The direction of $\overrightarrow{R}$ with respect to $\overrightarrow{F}_1$ is:

$$\acute{\phi} = \tan^{-1}\left(\frac{F_2\sin\theta}{F_1 + F_2\cos\theta}\right) \tag{12}$$

Procedure:

Part A: Two forces:

1. **Hang two forces on the force table at an angles (given in table(1)) and find the equivalent force which makes the pin at the center of the ring.**

2. **Compute $\overrightarrow{R}$ graphically (triangle method), by using graph paper.**

3. **Compute $\overrightarrow{R}$ by direct calculation.**

4. **Compute $\overrightarrow{R}$ by component method, by using graph paper.**

Name: **Grade:**

Students No.: **Date:**

Data and Calculation

Your data should presented in table (1) and (2), find the percentage error by comparing with the calculated values.

Part A: table 1

Method	$\lvert F_1 \rvert$	$F_2 \rvert$	θ_1	θ_2	F_x	F_y	$\lvert\overrightarrow{R}\rvert$	ϕ	error %
Force table					XXX	XXX			
Graphically					XXX	XXX			
Component									
Calculation					XXX	XXX			

where :

θ_1: **The angle that** $\overrightarrow{F_1}$ **makes with the positive x-axis.**

θ_2: **The angle that** $\overrightarrow{F_2}$ **makes with the positive x-axis.**

ϕ: **The angle that R makes with the positive x-axis.**

Discussion:

1. **Add the two vectors algebraically:** $\overrightarrow{u} = 1\widehat{i}+2\widehat{j}$, $\overrightarrow{v} = 2\widehat{i}$ -5$\widehat{j}$.

2. **Draw the two vectors described above and add them graphically.**

3. Split the vectors below into the two given components and add them up:

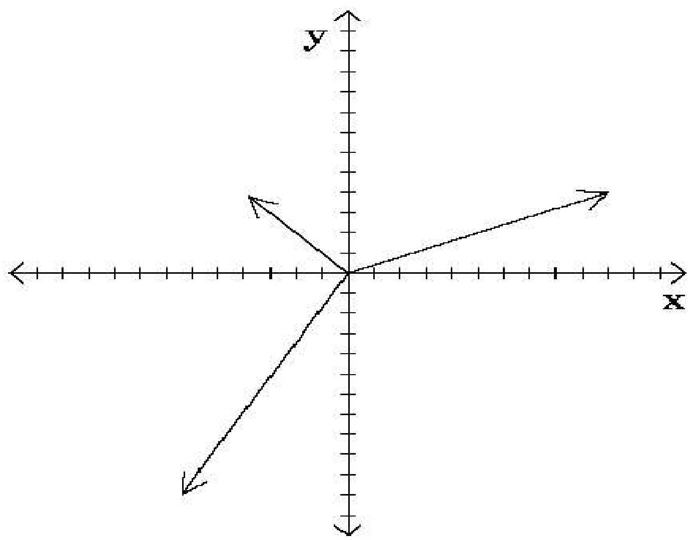


Figure 7:

Experimental No. (2)

Acceleration on an Inclined Plane

Objective:

1. **To determine the relation between x and t for an object moving under the action of constant acceleration.**

2. **To determine the acceleration due to the gravity g.**

Apparatus:

Air track, stop watch, Gliders.

Theory:

Consider an object resting on a friction less plane which is inclined at an angle θ from the horizontal as shown in Fig. (8).

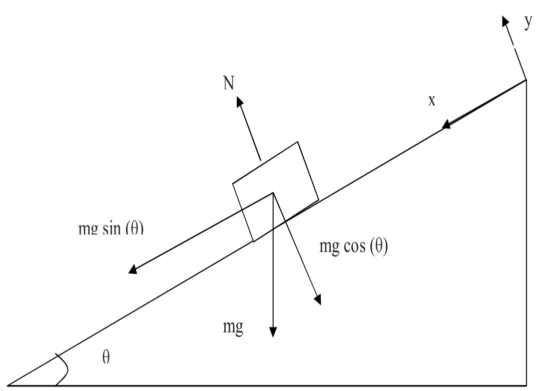


Figure 8:

The weight of the object m$\overrightarrow{g}$ is resolved into horizontal component mg$\sin(\theta)$ and perpendicular component mg$\cos(\theta)$, see Fig. (8).

Using newtons second law $\sum F_x = ma_x$

we have:

$$mg\sin(\theta) = ma_x \tag{13}$$

$$a_x = g\sin(\theta) \tag{14}$$

Where, a_x is the linear acceleration in the x- direction (along the plane).
The distance x traveled in the x-direction (along the plane) in a time t is given by:

$$x = v_o t + \frac{1}{2}a_x t^2 \tag{15}$$

Where, a_x is the linear acceleration along the plane, v_o is the velocity at t = 0.
Suppose the initial velocity v_o is 0, then:

$$x = \frac{1}{2}a_x t^2. \tag{16}$$

Plotting x vs. t^2 gives a straight line with slope s equal to $\frac{1}{2}a_x$, then using equation (14) we have:

$$S = \frac{1}{2}a_x = \frac{1}{2}g\sin(\theta). \tag{17}$$

$$g = \frac{2S}{\sin(\theta)}. \tag{18}$$

The relative error of the experimental results of g is given by:

$$\frac{\Delta g}{g} = \frac{\Delta S}{S} + \frac{\Delta\sin(\theta)}{\sin(\theta)} \tag{19}$$

$$\sin(\theta) = \tan(\theta) = \frac{H}{L} \Longrightarrow \frac{\Delta \sin(\theta)}{\sin(\theta)} = \frac{\Delta L}{L} + \frac{\Delta H}{H} \tag{20}$$

$$\Delta S = \frac{S_{max} - S_{min}}{2} \tag{21}$$

$$S = S_{av.} \simeq \frac{S_{max} + S_{min}}{2} \tag{22}$$

Procedure:

1. **Level the air track with the horizontal by using sir-screws.**

2. **Put a layer piece of wood under one end of the air track to obtain an inclined plane with an angle θ, where θ can be measured by finding $\tan(\theta)$ from Fig. (8).**

3. **Release the glider from a known point near the top end of the track, measured the time taken for the glider to strike the lower bumper. Repeat three times for the same distance. Let the time measured in the three cases t_1, t_2 and t_3, then find the average time t.**

4. **Repeat step 3 five times for different distances.**

5. **Tabulate your data in Table (2).**

Name:................. **Grade:.........**

Students No.:.................. Date:..../...../......

Data and Calculation

Table 2

Trial	**x (cm)**	$t_1(sec)$	$t_2(sec)$	$t_3(sec)$	$\bar{t}(sec)$	$t^2(sec)$
1						
2						
3						
4						
5						
6						

1. **Plot x vs. t^2.**
2. **Determine the slope of the strait line you obtained in step 1.**
3. **From the slope calculate the acceleration due to gravity g.**
4. **Calculate the error in the calculation of g.**
5. **Tabulate the experimental and the calculated results in table (3).**

$S(cm/sec^2)$	
$\Delta S(cm/sec^2)$	
$\sin(\theta)$	
$\Delta(\sin(\theta))$	
$g(cm/sec^2)$	
$\Delta g(cm/sec^2)$	

Questions:

1. **What is the velocity of the glider at the instant it strikes the lower bumper in terms of g, θ, and x?**

   ..

   ...

   ..

2. **Do you think that g is constant at all locations on the earth? Why?**

   ..

   ...

   ..

Discussion and Conclusion.

..

...

..

Experimental No. (3)

Newton's Second Law

Objective:

To verify Newton's second law, by:

1. **Investigating the dependence of acceleration of a body on its mass, when the net force is kept constant and,**

2. **Investigating the dependence of acceleration of a body on the net force, when its mass is kept constant.**

Apparatus:

Air track, Glider, Hanger, 2 Photogates, 5g, 10g,15g, 20g and 25g masses

Theory:

Newton's second law states that the acceleration of a body is proportional to the force acting on the body and inversely proportional to its mass:

$$\overrightarrow{F} = m\overrightarrow{a} \tag{23}$$

Figure(9) is a sketch of the apparatus used in the experiment. In this experiment a low friction air track will be used to test the validity of Newtons Second Law. A hanging mass will be attached to a glider placed on the air track by means of a light (negligible mass) string. By varying the amount of mass that is hanging we will vary the net force acting on this two body system. While doing this we will make sure to keep the total mass of the two body system constant by moving mass from the glider to the hanger. With the air track turned

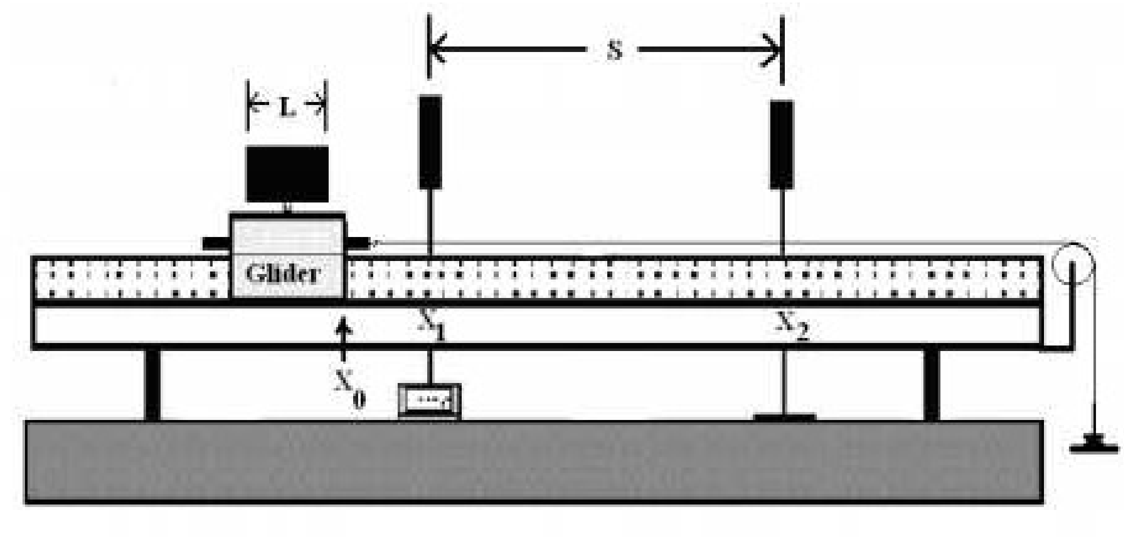


Figure 9:

on, the hanging mass will be released and the glider will pass through two photogate timers. The photogate timers will be used to measure two velocities Recall that $v = \frac{\triangle x}{\triangle t}$. In our case$\triangle x$ will be the length of a fin placed on top of the glider($= 5cm$). If you know the separation between the two photogate timers, you can use the following equation to determine the acceleration of the glider:

$$v_2^2 = v_1^2 + 2 * a * S \tag{24}$$

$$a = \frac{v_2^2 - v_1^2}{2S} \tag{25}$$

where v_2 is the velocity measured with the second photogate, v_1 is the velocity measured with the first photogate, a is the acceleration and S is the distance between the two photogate timers. Applying Newtons Second Law to the glider in the horizontal direction and using to the right as the positive direction yields:

$$M_H * g - T = M_H * a \tag{26}$$

$$T = M_G * a \tag{27}$$

$$afteraddtion \quad M_H * g = F_H = (M_H + M_G) * a \tag{28}$$

Where T is the tension in the string; $F_G = M_G * g$ is the weight of the glider; and $F_H = M_H * g$ is the weight of the hanging mass where g is the acceleration due to gravity.

Procedure:

I. Dependence of acceleration on mass at constant force.

1. **Set up the air track as shown in Figure (9). With the hanging mass disconnected from the glider and the air supply on, level the air track by carefully adjusting the air track leveling feet. The glider should sit on the track without accelerating in either direction. There may be some small movement due to unequal air flow beneath the glider, but it should not accelerate steadily in either direction.**

2. **Measure the length (L) of the fin on top of the glider and record it in your spreadsheet. See the Figure for a definition of various lengths that will be used throughout this experiment.**

3. **Measure the mass of the glider (M_{G0}) and empty hanger (M_{H0}) and record these masses in your spreadsheet.**

4. **Using the 5, 10 and/or 20 gram masses, place mass on the glider. Make sure to distribute the masses symmetrically so that the glider is balanced on the track and not tipping to one side. record this in your spreadsheet in the column labeled M_1.**

5. increase the mass on the glider up to five values and record the other quantities in the table 1.

6. Plot the inverse of the acceleration ($\frac{1}{a}$) against the added mass to the hanger M_1.

II. Dependence of acceleration on Force at constant mass.

1. Note that the total mass of your system ($M_G + M_H$) should remain constant throughout the experiment and always be equal to the value entered next to Total system mass ($M_{H0} + M_{G0} + 50$). You are just redistributing 50 grams of mass between the glider and the hanger during the experiment.

2. Let the glider accelerate with all the 50 grams on the glider and the hanger empty. Tabulate your data and calculations in table (2).

3. Repeat step 2 by removing weights from the glider 10 grams and add them to the driving load(hanger) keeping the same total mass of the system. and tabulate your data and calculations in table (2).

4. plot $F = (M_{Ho} + M_1)$*g Vs. a.

Name:................. Grade:......... **Data and Calculation**

$M_{Go} = ...gm,$ $M_{Ho} = ...gm.$

Table 1:

M_1	t_1	t_2	t_3	V_1	V_2	**a**	$\frac{1}{a}$
(gm)	**(sec)**	**(sec)**	**(sec)**	(cm/sec)	(cm/sec)	(cm/sec^2)	(sec^2/cm)

measured M_{Go}	from graph M_{Go}	$\frac{\Delta M_{Go}}{M_{GO}}\%$	accepted g	from graph g	$\frac{\Delta g}{g}\%$
(gm)	(gm)		(cm/sec^2)	(cm/sec^2)	

$$total\ mass = M_{Go} + M_{Ho} + ...gm$$

Table 2:

Net force F_H (dyne)	t_1 (sec)	t_2 (sec)	t_3 (sec)	V_1 (cm/sec)	V_2 (cm/sec)	a (cm/sec^2)

slope=total mass (gm)	(m_{Ho} from slope) (gm)	$\frac{\Delta m_{H0}}{m_{H0}}\%$

Experimental No. (4)
Friction

Objective:

- **To determine the Coefficient of Static Friction and kinetic Friction**

Apparatus:

- **Horizontal plane (of variable angle to be Incline plane), Frictionless pulley, Wooden block, String, Mass holder and various masses.**

Theory:

Friction is a resisting force that acts along the tangent to the two surfaces in contact when one body slides or attempt to slide across another. The direction of the fractional force on each body is to oppose that body's motion. It is an experimental observation that frictional forces depend upon the nature of the materials in contact, including their composition and roughness, and the normal force N between the surfaces. Normal force is the force that each body exerts on the other body, and it acts 90 to each surface. The frictional force is directly proportional to the normal force. To a good approximation, the frictional force seems to be independent of the apparent area of contact of the two surfaces. There are two different kinds of friction:

Static friction Occurs when two surfaces are still at rest with respect to each other, but an attempt is being made to cause one of them to slide over the other one. Static friction force fs arises to oppose any force trying to cause motion tangent to the surfaces. It increases in response to such applied forces up to some maximum value f_s^{max} that is determined by a constant characteristic of the two surfaces. This is

called the coefficient of static friction μ_s. The frictional force for static friction is given by:

$$f_s \leq \mu_s N \tag{29}$$

Where N stands for the normal force between the two surfaces. The meaning of equation-1 is that the static frictional force varies in response to the applied forces from zero up to a maximum value given by the equality in that equation. If the applied force is less than the maximum given by equation-1, then the frictional force that arises is simply equal to the applied force, and there is no motion. If the applied force is greater than the maximum given by equation-1, the object will begin to move, and static friction conditions are no longer valid. Kinetic friction The other kind of friction, occurs when two surfaces are actually moving with respect to each other. It is called kinetic friction, and it is characterized by a constant ?k, which is called the coefficient of kinetic friction. The kinetic frictional force f_k is given by

$$f_k = \mu_k N \tag{30}$$

The kinetic frictional force is dependent on the speed of motion , but we can neglect this in our experiment. In general $\mu_s > \mu_k$. This means that when enough force is exerted to overcome static frictional forces, that same force is sufficient to accelerate an object because once it is moving, the kinetic frictional force is less than the applied force.

Procedure

- Horizontal Plane: Consider the horizontal position of the plane, a string running over a pulley mounted to the board and down to a mass m as shown in Figure-1.

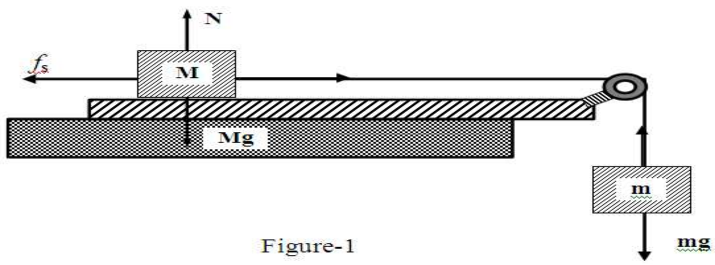


Figure 10:

1. **Find a force, applied to the block of mass M by means of slowly adding masses to m until the block (M) nearly to slip over the plane , this is the force of static friction f_s.**
2. **repate the previous step by increase the mass m until the block (M) begins to slip slowly with constant velocity on the horizontal plan, this is the force of Kinetic friction f_k**
3. **Tabulate your results in table (1)**

- **Inclined Plane:**

1. **Put the wooden block on the horizontal plan and start to increase the angle θ of inclination until the block is nearly to slip down at an angle θ_s, (at which , any increment in θ,the block will slide down with some acceleration). as shown in Figure-2**
2. **Fix the plane. Measure the vertical height (h) and the horizontal distance (b). Tabulate your results in table-2.**
3. **Add a mass 500 g to the block and repeat the steps1,2 . Tabulate your results in table-2.**
4. **Refer to Figure-3, Fix the Inclined plane at constant angle θ,**

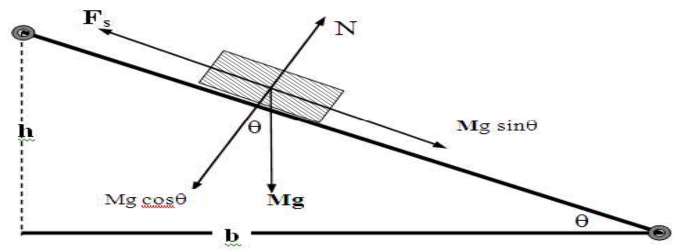


Figure 11:

tie the block to the string, which passes over the pulley to the weight hanger with hanged mass m (Figure-3).

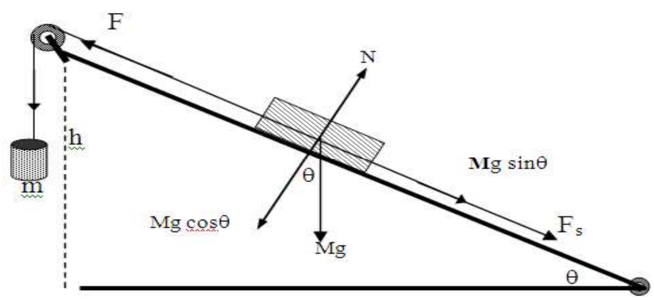


Figure 12:

5. **Start adding small masses to the hanger (m) until the block starts to move up slowly in constant velocity. Tabulate the values of the block mass (M), the total hanged mass (m) and the inclination angle θ in table-3.**
6. **Change the angle ,repeat steps 3,4,5 . Tabulate your data.**

Name: **Grade:**

Students No.: **Date:**

Data and Calculation

	$M(kg)$	$m_s(kg)$	$N = Mg$	$f_s = m_s g$	$\mu_s = \frac{f_s}{N}$	$m_k(kg)$	$f_k = mg$	$\mu_k = \frac{f_k}{N}$
without load								
with load...								

.

The value of $\mu_s = ...,$ $\mu_k = ...$

	b(cm)	**h(cm)**	$\tan\theta_s = \frac{h}{b}$	$\mu_s = \tan\theta_s$
without load				
withload				

The value of $\mu_s = ...$

.

	m_k	θ	$\cos\theta$	$\tan\theta$	μ_k
M=......					
.....					

$\mu_k = \frac{m}{M\cos\theta} - \tan\theta$

....

Questions: 1- Prove the following equation $\mu_k = \frac{m}{M\cos\theta} - \tan\theta$

.

Experimental No. (5)

Uniform Acceleration Motion

Objective:

To study the motion of freely falling bodies.

To evaluate the acceleration due to the gravity.

Apparatus:

Free falling apparatus with electronic timer and meter stick.

Theory:

When objects of different masses are allowed to fall freely from rest, the objects are observed to fall identical distances in identical times. The average velocities and the final velocities of the masses are also identical. Hence the accelerations of the objects are equal. So, all objects accelerate at the same rate under the influence of gravity. We can derive an equation for the distance an object falls in a time t.

If you let the mass (m) falls freely from rest then the distance made:

$$y = \frac{1}{2}gt^2 \tag{31}$$

From the last equation we see that: if we plot a graph of y versus t^2 we

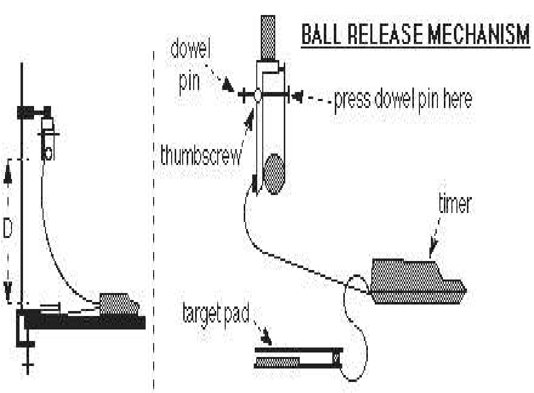


Figure 13:

get a straight line whose slope is equal to $S = \frac{1}{2}g$. So by measuring the distance and time we can experimentally determine the acceleration due to gravity.

Procedure:

A- Use a free fall distance of about 0.80 m, make three measurements of the free fall for two steel ball and for the big copper ball.

Note you can use any three different masses.

B-

1. **Turn the timer switch.**
2. **Put the small ball in the ball release mechanism.**
3. **Measure and record the distance from the bottom of the steel ball to the target pad on the ball receptor.**
4. **Release the ball and record the time.**
5. **Obtain three values of the fall time for each release and find the average time.**
6. **Plot y versus t^2, draw smooth curve through the points.**
7. **Find g from the graph and calculate the error, using the following law:**

$$error\% = \frac{g_{theoritical} - g_{experimental}}{g_{theoritical}} X100 \tag{32}$$

Name: **Grade:**

Students No.: **Date:**

The density of the steel is $7.9gm/cm^3$**, copper 8.23**gm/cm^3

distance	**Mass of the ball**	t_1	t_2	t_3	$\bar{t}$
0.80m					
0.80m					
0.80m					

Trial number	**Mass of the ball**	t_1	t_2	t_3	$\bar{t}$	t^2	**y (m)**
1							
2							
3							
4							
5							

from the graph of y versus t^2 **find the slope.**

S=..............., g=.................

calculate the error in g.

Questions:

1. **Prove that covered distance in the gravity of the earth does not depend on the mass of the falling object.**

2. **Derive equation no.1.**

Experimental No. (6)

Atwood's Machine

Objective:

The purpose of this laboratory activity is to study the relationship between force, mass, and acceleration using an Atwood's Machine.

Apparatus:

Pulley, loads with electronic timer and meter stick.

Theory:

The acceleration of an object depends on the net applied force, and the mass. In an Atwood's Machine, the difference in weight between two hanging masses determines the net force acting on the system of both masses. This net force accelerates both of the hanging masses; the heavier mass is accelerated downward, and the lighter mass is accelerated upward.

In the free body diagram of the Atwood's machine, T is the tension in the string, M_1 is the lighter mass, M_1 is the heavier mass, and g is the acceleration due to gravity. Assuming that the pulley has no mass, the string has no mass and doesn't stretch, and that there is no friction, the net force on M1 is the difference between the tension and $M_1 g$ $(T > M_1 g)$. The net force on M_2 is the difference between the tension and $M_2 g$ $(T < M_2 g)$.

Solve for "a", the acceleration of the system of both masses. The theoretical acceleration is "g" times the difference in mass divided by the total mass.

$$a = g\frac{M_2 - M_1}{M_2 + M_1} \tag{33}$$

From the analysis of the force equation we see that: if we plot a graph of y versus t^2 we get a straight line whose slope is equal to $S = \frac{1}{2}a$. So

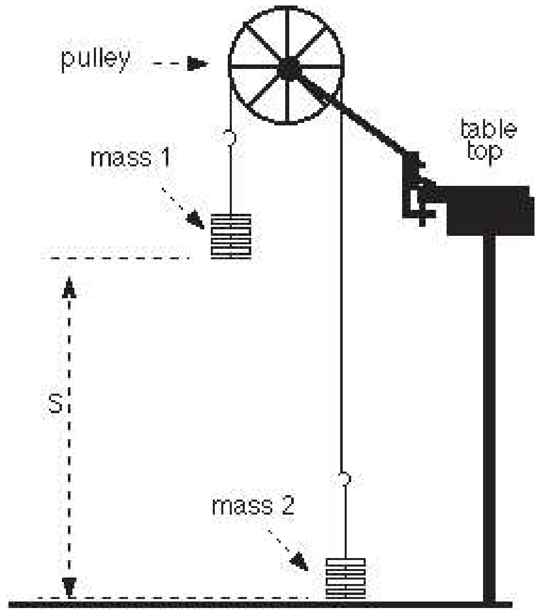


Figure 14:

by measuring the distance and time we can experimentally determine the acceleration due to gravity.

Procedure:

1. **Mount a clamp to the edge of a table. Place the Smart Pulley in the clamp so that the Smart Pulley's rod is horizontal**
2. **Use a piece of thread about 10 cm longer than the distance from the top of the pulley to the floor. Place the thread in the groove of the pulley**
3. **Fasten mass hangers to each end of the thread.**
4. **Place about 100 grams of mass on one mass hanger and record the total mass as M_1. Be sure to include the 50 grams from the mass hanger in the total mass. Place slightly more than 100 grams on**

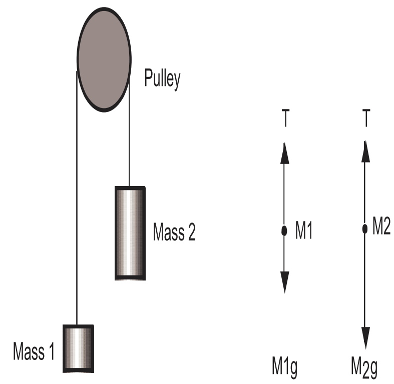


Figure 15:

the other hanger. Record this total mass as M_2.

5. **Move the heavier of the two masses upward until the lighter mass almost touches the floor. Hold the heavier mass to keep it from falling. measure the time it takes the heavier mass to reach the floor three times.**

6. **use the distance and the average time square to calculate the experimental acceleration(a_{exp}) from the equation:**

$$y = \frac{1}{2}a_{exp}t^2 \tag{34}$$

7. **change the mass on the hangers each trial and try to make the deference between them is small compared to the total masses.**

Name: **Grade:**

Students No.: **Date:**

	M_1	M_2	t_1	t_2	t_3	$\bar{t}$	t^2	**y (m)**	a_{th}	F_{net}	a_{exp}
Run1											
Run2											
Run3											
Run4											
Run5											

from the graph of a_{exp} versus $\frac{M_2-M_1}{M_2+M_1}$ find the slope.

S=..............., g=..................

calculate the error in g.

...

Questions:

1. **Suppose there is an Atwood's machine with M_1 = 0.5 kg, M_2 = 1.0 kg. What is the acceleration of such a system if the friction is negligible $(g = 10m/s^2)$?**

2. **What is the net force in an Atwood's machine if M_1 = 1 kg and M_2 = 2 kg?**

Experimental No. (7)
Conservation of Energy

Objective:

Verification of the conservation of energy law.

Apparatus:

Flex-track, balls, ruler, and carbon paper.

Theory:

If a ball of mass m is released from point A on the track AB, then the conservation of energy gives:

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + workdoneagainstfriction. \tag{35}$$

where mgh is the potential energy of the ball relative to point B on

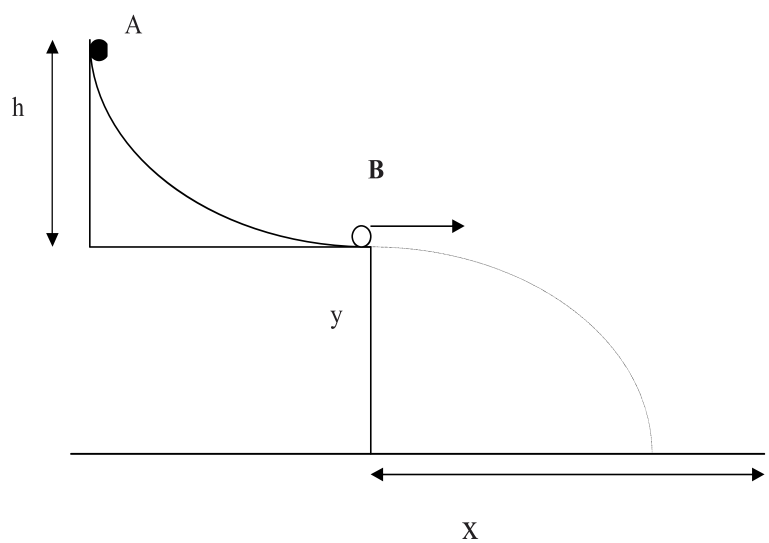


Figure 16:

the track (see fig. 1)

$\frac{1}{2}mv^2$ is the transitional kinetic energy of the ball at point B.

$\frac{1}{2}I\omega^2$ is the rotational kinetic energy of the ball at point B.

ω is the angular velocity of the ball at point B (and equals $\frac{v}{r}$).
I is the moment of inertia of the sphere about any axis passing through its center and is given by:$I = \frac{2}{5}mr^2$
If one neglect friction force, velocity can be expressed as:

$$v = \sqrt{\frac{10}{7}gh} \tag{36}$$

(Note that the velocity of the ball at point B is independent of its mass).
If we further assume that the track, at B is perfectly horizontal, then the ball will be treated as a projectile of horizontal velocity v. The horizontal velocity of the ball at point B could be found by different method . This is done by measuring x and y (refer to the figure) where,

$$\grave{v} = \frac{x}{t} = \frac{x}{\sqrt{\frac{2y}{g}}} \tag{37}$$

Procedure:

1. Weigh a small ball(solid sphere) and record its mass.(If possible use an electrical balance).

2. Release the ball from point A on the track, (point A is arbitrary).

3. Repeat step 2 for the same height (for the same ball) two times.

4. Indicate the center of the group of points made by the ball when it hits the carbon paper and measure the horizontal displacement x.

5. Calculate v and v' by using Eq.(2) and Eq.(3) respectively.

6. **Repeat the outlined procedure for another two balls of different masses.**

7. **Arrange your data as in table(l).**

Name: **Grade:**

Students No.: **Date:**

	m	**h**	**y**	**x**	**t**	**v**	**v'**	**mgh**	$\frac{7}{10}mv^2$	$\frac{7}{10}mv'^2$
Run1	m_1	h_1								
Run2	m_1	h_2								
Run3	m_2	h_1								
Run4	m_2	h_2								
Run5	m_3	h_1								
Run6	m_3	h_2								

h_1=**...............cm,** h_2=**..................cm.**

Questions:

1. **Compare the values calculated in columns 9, 10 and 11, Justify any difference?**

Discussion and Conclusion:

Experimental No. (8)

Conservation of Linear Momentum

Objective:

Verification of the conservation of Linear Momentum.

Apparatus:

Flex-track, balls, ruler, and carbon paper.

Theory:

The law of consecration of linear momentum states that:

"bf the total linear momentum of an isolated system is constant"

$$\sum_{i=1}^{N} \overrightarrow{P_i} = \sum_{i=1}^{N} \overrightarrow{P_f} = constant \tag{38}$$

For a system consisting of two particles, the law of conservation of

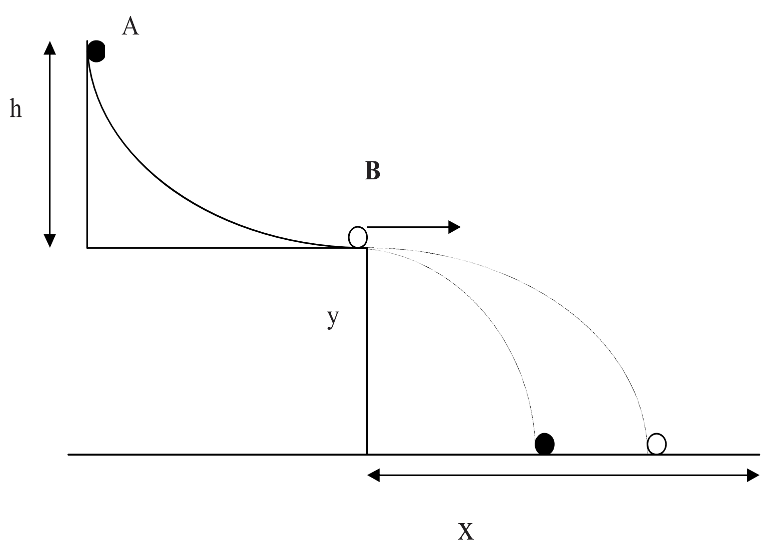


Figure 17:

linear momentum in a collision reduces to:

$$(\overrightarrow{P_1} + \overrightarrow{P_2})_{beforecollision} = (\overrightarrow{P_1} + \overrightarrow{P_2})_{aftercollision} \tag{39}$$

$$M\overrightarrow{V} + m\overrightarrow{v} = M\overrightarrow{V'} + m\overrightarrow{v'} \tag{40}$$

if we choose m initially to be at rest, the equation will be given as:

$$M\overrightarrow{V} = M\overrightarrow{V'} + m\overrightarrow{v'} \tag{41}$$

$$M\frac{\overrightarrow{r_1}}{t} = M\frac{\overrightarrow{r'_1}}{t} + m\frac{\overrightarrow{r'_2}}{t} \tag{42}$$

Where,

V : is the velocity of the mass M before the collision in x direction,$\overrightarrow{r_1}$ **is the position vector of the falling ball without collision,** V', $\overrightarrow{r'_1}$**: is the velocity and displacement of the falling mass after collision,** v', $\overrightarrow{r'_2}$**: is the velocity and displacement of the hitted mass after collision, since we choose the two masses are equaled, and the time of flight for all the masses is the same, the above equation become:**

$$\overrightarrow{r_1} = \overrightarrow{r'_1} + \overrightarrow{r'_2} \tag{43}$$

Procedure:

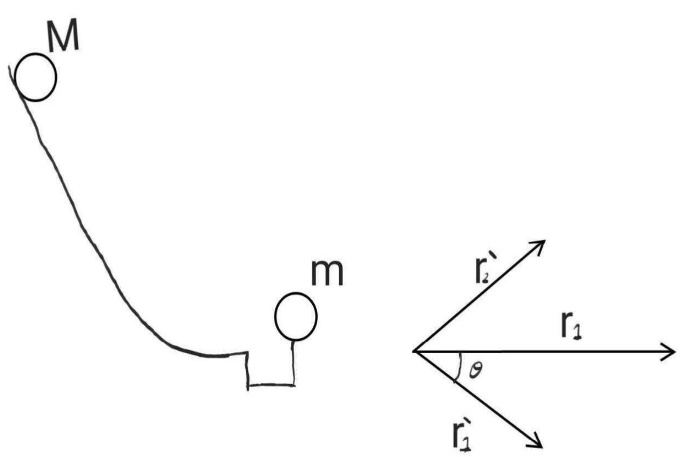


Figure 18:

1. **Place one ball near the end of the horizontal portion of the flex-track (see Fig. 1)**

2. **Release the ball from point A on the track and mark the position of the ball as** $\vec{r_1}$**.**

3. **Record the height h from which the ball is released. This should be measured . relative to the horizontal end of the track (see the figure).**

4. **Rerelease the ball again from the same height and put the other ball to make collision. Make sure that the collision is making small angle between the balls**

5. **Measure the distance of ball one and mark it as** $\vec{r}_1$**, and the other as** $\vec{r}_2$ **.**

6. **Repeat the outlined procedure for the same pair of balls and for the same h with a slight change in angle.**

7. **Repeat the above steps for the same pair of balls but for a different h.**

8. **Tabulate your results as in Table (1).**

Name: **Grade:**

Students No.: **Date:**

	h	θ	$\overrightarrow{r_1}$	$\overrightarrow{r_1'}$	$\overrightarrow{r_2'}$	$\overrightarrow{R_1'}=\overrightarrow{r_1'}+\overrightarrow{r_2'}$	**error**
Run1							
Run2							
Run3							
Run4							
Run5							
Run6							

Questions:

1. **What is the main sources of error in your experiment?**

Discussion and Conclusion:

Experimental No. (9)

Pendulum

Objective:

1. **To measure the dependence of period on length of the pendulum**
2. **To measure the acceleration of gravity.**
3. **To determine the spring's constant.**

Apparatus:

Pendulum bob, spring, slotted weights, meter and stop watch.

Theory:

All vibrating systems have frequency (f) at which they vibrate. The frequency is how many vibrations the system makes per unit time. Sometimes it is more useful to work with the period (τ) of the vibration or oscillation, and is the reciprocal of frequency. The size of the maximum displacement from the rest position is called the amplitude A. These quantities are related in such a way that they can describe the motion of an oscillating system mathematically. If we have a particle which is oscillating in the y-axes, the location in the y-axis at any given time (t) from the start of oscillation, can be found from the equation:

$$y = A\sin(2\pi ft) = A\sin(\omega t) \tag{44}$$

The velocity of the oscillating particle can be found from the displacement by taking the derivative of it with respect to time, the acceleration also can be found by taking the second derivative of displacement with respect to time as shown:

$$v = \frac{dy}{dt} = 2\pi fA\cos(2\pi ft) = \omega A\cos(\omega t) \tag{45}$$

$$a = \frac{d^2y}{dt^2} = -(2\pi f)^2 A \sin(2\pi f t) = -(2\pi f)^2 y \quad (46)$$

From equation (3)we can get the frequency:

$$f = \frac{1}{2\pi}\sqrt{(-\frac{a}{y})} \quad (47)$$

We will examine the two type of simple harmonic motions in this experiment:

1. **the first is a mass attached to a spring displaced a distance (-y) from the equilibrium point, since the displacement is not big the restoring force will be Hook's force (F=-ky), where, k is the spring constant. Using Newton's second law F= ma. We can write:**

   $$ma = -ky; \frac{-a}{y} = \frac{k}{m} \quad (48)$$

   Substituting into equation (4) will give us the frequency:

   $$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad (49)$$

   And the periodic time is:

   $$\tau = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}} \qquad (masslessspring) \quad (50)$$

   So far, we have assumed that the spring is massless, but the spring has a mass m', so its inertia affects the period of oscillation. This effect is very small and can be neglected. So from Eq.(7) you can predict the spring's constant.

2. **The other example of simple harmonic motion that we will examine is the simple pendulum, which is consist of a mass (m), called the bob, on the end of the string of length L. If we move the.bob a way from the rest position through some angle of displacement**

θ **As shown in Fig.(l), the bob will be acted upon by a restoring force due to gravity trying to move the bob back to its rest position. The magnitude of this force depends on the mass of the bob, acceleration due to gravity (g) and sine of the angle through which the bob has been moved. That is** $F = -mg\sin\theta$ **. So if we apply Newton's second law we get:**

$$F = -mg\sin\theta = ma; \qquad where,\ \sin\theta = \frac{y}{L} \tag{51}$$

As θ **is small we can express** $\sin\theta = \theta$**.**

Procedure:

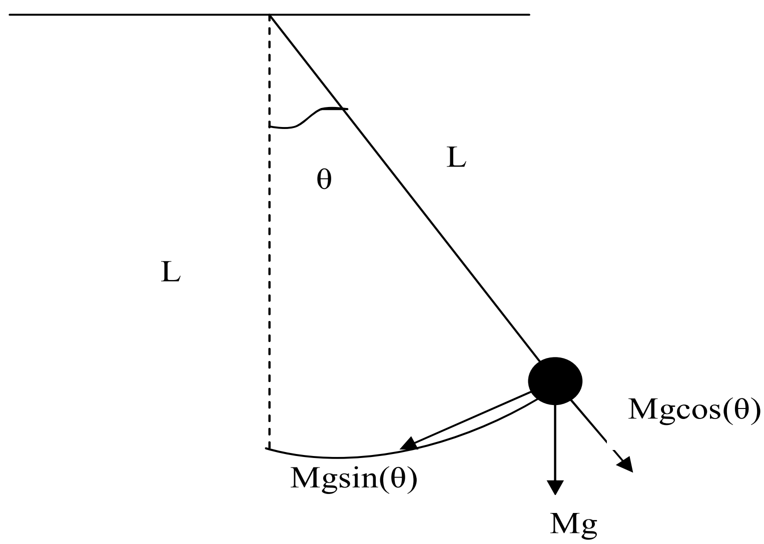


Figure 19:

- **For a mass on a spring: Part 1:**
  1. **Suspend the spring vertically from a rigid support.**
  2. **Use the slotted weights to elongate the spring, and record the displacements from the equilibrium position.**

3. **Tabulate your data as in table(l).**
4. **Plot x (meter) versus F= m *g (Newton) and from the slope find K of the spring.**

Part 2:

1. **Attach a mass to the spring and pull it downward a distance (A) from the equilibrium position.**
2. **Find the period of a vertical oscillation, use the stop watch to determine the time needed for 10 oscillations, do this twice and then find the average.**
3. **Tabulate your data as in table(2).**
4. **Plot T^2 versus m, using table (2) and find k from the graph.**

- **pendulum:**

1. **With the pendulum provided, displace the bob to one side and release (use small θ), use the stop watch to determine the time needed for 10 oscillation, do this step two times and then find the average.**
2. **Tabulate your data as in table(3)**

Name: **Grade:**

Students No.: **Date:**

Data and Conclusion:

Total Added mass	**Force**	**elongation**	**Spring constant**
m(kg)	**F=m*g(N)**	**x(m)**	**k(N/m)**

Draw F Vs x and fine k from the slope.................

Added mass	**Time for**	**10 oscillation**	**Period**	**Square period**
m(kg)	t_1	t_2	$\tau = \frac{t_1+t_2}{20}(sec)$	$\tau^2(sec^2)$

Draw τ^2 Vs m, find Slope = ...   k = ...N/m   intercept=..........

Pendulum Length	**Time for**	**10 oscillation**	**Period**	**Square period**
L(m)	t_1	t_2	$\tau = \frac{t_1+t_2}{20}(sec)$	$\tau(sec^2)$

Draw τ^2 Vs L

Find Slope=............., g = ...m/sec^2 **,**$\frac{\Delta g}{g}$**%=.............**

Questions:

1. **Compare the two values of the spring's constant that you obtained from table(1) and table(2).**

2. **Is the period of the simple pendulum, in general depends on the amplitude?**

3. **what is the relation between k's and k'eq for parallel and series combination?**

4. **If the length of pendulum clock depends on temperature, in summer will the clock gain or lose time? Explain your answer.**

Experimental No. (10)

THE VISCOSITY

Objective:

- **To show that a small sphere falls with constant terminal velocity (v).**
- **To determine the viscosity coefficient η of glycerin.**

Apparatus: Viscosity is determined using the falling sphere viscometer which is composed of:

- **Glass cylinder : one meter Length, 0.1m inner diameter,**
- **Glycerin, shamboo and honey.**
- **Ball bearings of 3-8 mm diameter (density 7.8 gm/cm^3)**
- **Small magnet; Acetone ; Two rubber bands;**
- **Meter stick; Micrometer; Caliper; Stop watch.**

INTRODUCTION:

The resistance to the fluid flow due to the internal friction between adjacent fluid layers is called viscosity. If a sphere of diameter d and density ρ is allowed to fall from rest (Fig.20) through a liquid of density ρ_o , it will accelerate by the gravitational force F_G opposed by viscous force F_D, and the buoyant force of the fluid, F_B, until it reaches a constant terminal velocity, v_t. At this point, F_G is balanced by the F_D and F_B :

$$F_D + F_B = F_G \tag{52}$$

$$Gravitational force \qquad F_G = mg \tag{53}$$

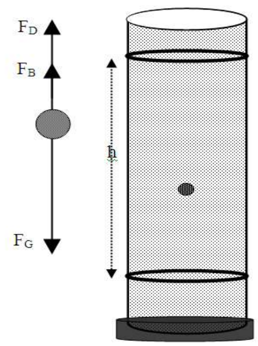


Figure 20:

$$Buoyant force \qquad F_B = \frac{1}{6}\pi d^3 \rho_o g \tag{54}$$

$$The \textbf{ viscous force} \qquad \mathbf{F_D = 3\pi\eta d\nu} \tag{55}$$

Where: η is the coefficient of viscosity of the fluid. Using this balance, the student can show that the coefficient of viscosity η is given by:

$$\eta = \frac{1}{18}(\rho - \rho_o)g\frac{d^2}{v} \tag{56}$$

Experimental Procedure:

Measure the liquid temperature

- **To show that a small sphere falls with constant terminal velocity (v).**

  1. **Select a number of ball bearings of the same diameter. Adjust the distance between the two rubber bands, so that they are separated by a distance, h, of about 80 cm and record this distance. Start with the upper rubber band at about 10 cm below the surface of the fluid in the cylinder.**

  2. **Drop one ball bearing sphere down the central part of the cylinder. Use the stop watch to find the time, t, it takes**

the sphere to traverse the distance between the two rubber bands.

3. **Keeping the lower band fixed, lower the upper rubber band by 10 cm at a time. For each new distance, obtain the value for the time it takes the sphere to transverse the distance h. Tabulate your data in a table similar to Table-1**

- **Determination of the viscosity coefficient η of liquid.**

1. **Place the two rubber bands on the oil filled cylinder so that one is located 10 cm below the oil surface and the other is at 15 cm above the bottom of the cylinder.**
2. **Select five spheres of different diameters, and measure their diameter using a micrometer. Clean the spheres with acetone and dry them. Hold each sphere carefully with a tweezers and drop it in the oil. Measure the time of fall between the two rubber bands t. Tabulate your data in Table-2**

Name: **Grade:**

Students No.: **Date:**

Data and Data Analysis

- **To show that a small sphere falls with a constant terminal velocity**

Distance h(cm)	Time of Fall t(s)	Terminal Velocity $v = \frac{h}{t}$

Plot a graph between the distance h (cm) and the time t (s). Discuss your results and observations.

.

- **Determination of the coefficient of viscosity.**

Sphere density (steel) ρ = **7.85** gm/cm^3; **Liquid of density** $\rho_o =$ $...gm/cm^3$;

h= cm.

Diameter d(cm)	d^2	t	v	η

The average value of η = **...........poise**

Plot a graph between the values of d^2 **against, v. Determine the slope of the graph.; Slope= ....** η**=............**