

Experiment No (4)

Force Table

(Addition of Vectors)

Purpose

The purpose of this experiment is to use the force table to experimentally determine the force which balances two other forces. This result is checked by adding the two forces using their components and by graphically adding the forces.

Theory

Many physical quantities can be completely specified by their magnitude alone. Such quantities are called **scalars**. Examples include such diverse things as distance, time, speed, mass and temperature. Another physically important class of quantities is that of **vectors**, which have direction as well as magnitude.

- **Experimental Method:** Two forces are applied on the force table by using 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** ($\vec{F}_E$) since it is the force which established equilibrium. The equilibrant is not the same as the resultant ($\vec{F}_R$). The resultant is the addition of the two forces. While the equilibrant is equal in magnitude to the resultant, it is in the opposite direction because it balances the resultant (see Fig.4.1). So the equilibrant is the negative of the resultant:

$$-\vec{F}_E = \vec{F}_R = \vec{F}_A + \vec{F}_B \quad (4.1)$$

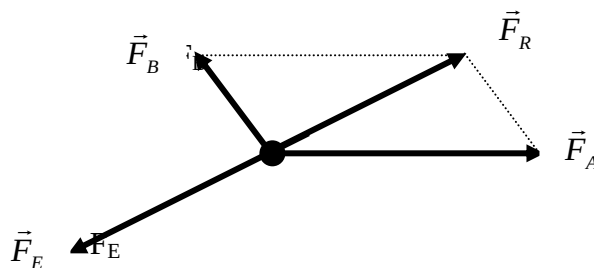


Figure 4.1: The equilibrant balances the resultant

- **Analytical Method** (*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:

$$\vec{F}_A = A_x \hat{x} + A_y \hat{y}, \quad \vec{F}_B = B_x \hat{x} + B_y \hat{y} \quad (4.2)$$

where A_x is the component of the vector $\vec{F}_A$ and $\hat{x}$ is the unit vector in the x -direction as shown Fig. 4.2. To determine the sum of $\vec{F}_A$ and $\vec{F}_B$, the components are added to get the components of the resultant $\vec{F}_R$.

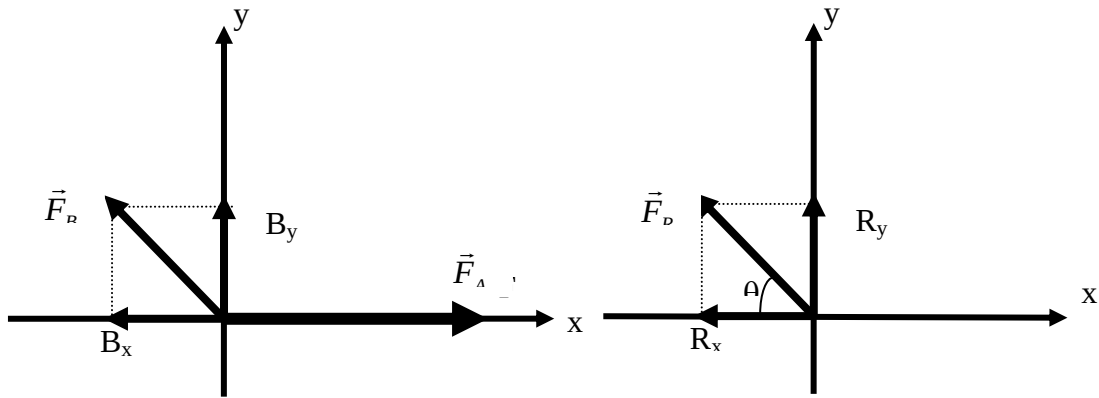


Figure 4.2: Vector Components

$$\vec{F}_R = (A_x + B_x) \hat{x} + (A_y + B_y) \hat{y} = R_x \hat{x} + R_y \hat{y} \quad (4.3)$$

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 (R_x and R_y) must be combined using the Pythagorean theorem since the components are at right angles to each other:

$$|F_R| = \sqrt{R_x^2 + R_y^2} \quad (4.4)$$

and using trigonometry gives the angle:

$$\tan \theta_R = \frac{R_y}{R_x} \quad (4.5)$$

- **Graphical Method:** Two forces are added together by drawing them to scale using a ruler and protractor. The second ($\vec{F}_B$) is drawn with its tail to the head of the first force ($\vec{F}_A$). The resultant ($\vec{F}_R$) is drawn from the tail of the $\vec{F}_A$ to the head of $\vec{F}_B$ as shown in Fig.4.3. 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.

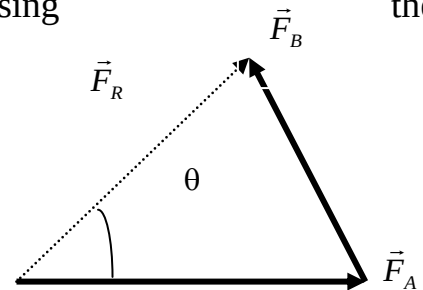


Figure 4.3: Adding vectors head to tail

Apparatus:

Force table, pulleys, weight hangers and set of slotted weights.

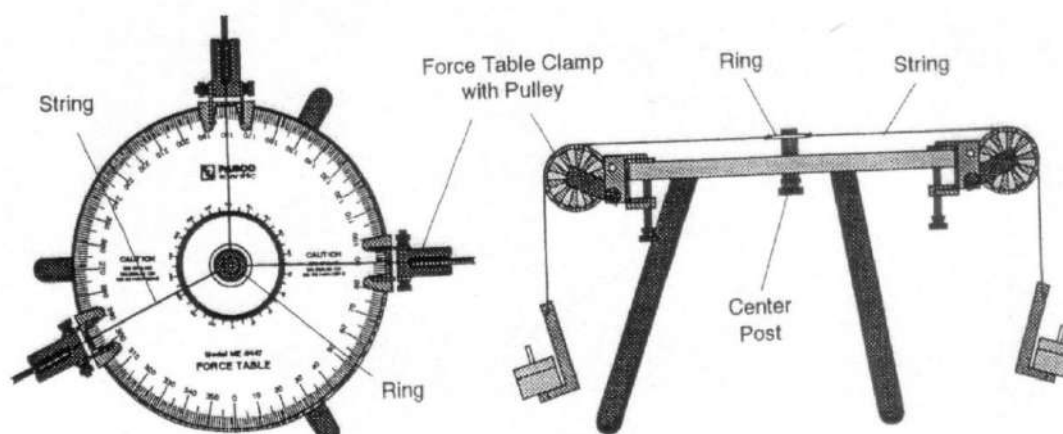
Procedure:

- 1) Place m_1 on a hanger at 30° angle on the force table.
- 2) Place the mass m_2 over another hanger and m_3 over the third one.
- 3) Change the angle (θ_2) of the second mass m_2 and the angle (θ_3) of the third mass m_3 until you get an equilibrium.(The ring should be centered over the post when the system is in equilibrium)
- 4) Record the values of m_2 , m_3 , θ_2 , and θ_3 in the table.
- 5) Draw a vector diagram to scale using a scale of 0.25 N per cm, and determine graphically the direction and magnitude of the resultant using the parallelogram method.
- 6) Using the trigonometry, calculate the components of $\mathbf{F}_1$ and $\mathbf{F}_2$ and use the analytical method to determine the resultant force (direction and magnitude).

7) Compare the results with the actual experimental values from the force table.

Results

Mass	Force	Direction
$m_1 =$	$F_1 =$	$\theta_1 =$
$m_2 =$	$F_2 =$	$\theta_2 =$
$m_3 =$	$F_{\text{equilibrant}} =$	$\theta_3 =$
The resultant force =		
Its direction =		



Method	Equilibrant (F_E)	
	Magnitude	Direction (θ)
Experiment (Force table) :		
Component: $R_x =$ _____ $R_y =$ _____		
Graphical:		

Experiment No. (11) Kinematics in one-dimension

Uniformly Accelerated Motion on the Air Table

Objective

To study the motion of an object moving along an inclined plane and the relationships between position, velocity and acceleration of an object.

Apparatus

Air table, pucks, air supply, sparktimer, recording paper, meter.

Brief Description:

In order to study the motion of an object moving along a straight line, one usually defines an axis along the direction of motion.

The **displacement** of an object over a given time interval is defined as the difference between the final and the initial positions of the object

$$\Delta x = x_f - x_i$$

Velocity is defined as the rate at which displacement takes place. Velocity can be seen as the slope of the position/ time curve.

$$\text{Average velocity } \bar{v} = \frac{\Delta x}{\Delta t}, \text{ instantaneous velocity } v = \frac{dx}{dt}$$

Acceleration is the rate at which speed is changing.

$$\text{Average acceleration } \bar{a} = \frac{\Delta v}{\Delta t}, \text{ instantaneous acceleration } a = \frac{dv}{dt}$$

Thus the acceleration can be obtained by measuring the slope of the velocity/time curve.

Theory:

To investigate the one-dimensional motion of a puck on an air table, we choose an arbitrary point near the beginning of the motion as the origin of the coordinate system. We determine the location of the puck by the position x of sparks on the recording paper at a constant time interval between the marks on the paper. If the

initial coordinate is x_i at some time t_i , and its later coordinate is x_f at some later time t_f , then the displacement Δx between those coordinates is given by $\Delta x = x_f - x_i$

Although displacements are generally vector quantities, for the special case of one-dimensional motion in one direction, it is sufficient to consider only the magnitude of the displacements. All displacements for this laboratory will be positive because the puck moves in one direction.

The average velocity $\bar{v}$ is given by

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

The average velocity is defined over some time interval Δt that is finite. The definition of instantaneous velocity, which is the velocity at some instant is the limit of the average velocity as the time interval Δt approaches zero. The average acceleration $\bar{a}$ is the time rate of change of the instantaneous velocity and is given by

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

In this laboratory the special case of constant acceleration will be the only case that is considered. When the initial velocity at $t=0$ has a value of v_0 ,

$$v = v_0 + at$$

This equation states that for constant acceleration, the instantaneous velocity increases linearly with time from its initial value of v_0 at $t=0$ to later values of v at any later time t . For constant acceleration there is a simple relationship between the average velocity and the instantaneous velocity. Because the velocity increases linearly with time, the average velocity during each time interval is equal to the instantaneous velocity at the middle of the time interval.

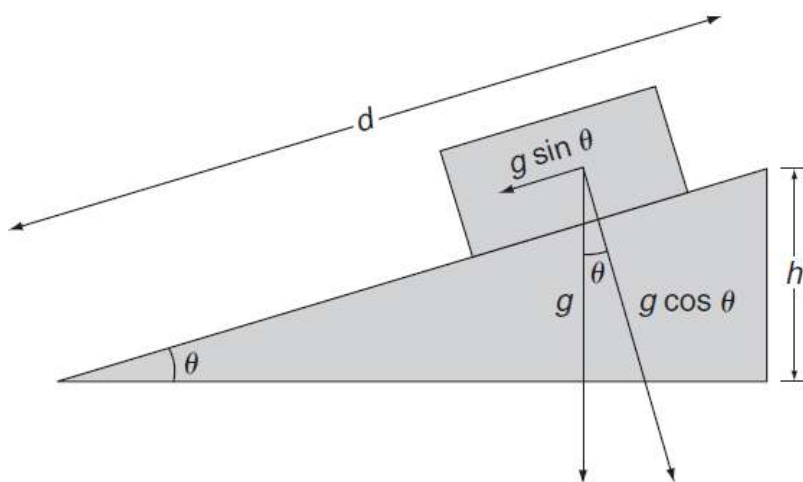
For constant acceleration, a determination of the average velocity as a function of time leads to a knowledge of the instantaneous velocity as a function of time. Assume that the coordinate position of some object is measured at fixed time intervals of 0.100 seconds. The average velocity during the interval from $t=0$ to $t=0.100$ seconds would equal the instantaneous velocity at $t=0.050$ seconds (the middle of the time

interval between $t=0$ and $t=0.100$ seconds). Similarly, the average velocity during any chosen interval is the same as the instantaneous velocity at the middle of that interval. When the instantaneous velocity is known as a function of time, that data can be fit to Equation 4 by a linear least squares fit to obtain the initial velocity v_0 at $t=0$ and the acceleration a .

The acceleration of an object down an inclined plane is a component of the acceleration due to gravity g as shown in Figure (11-1). The component of g pointing parallel to the plane causing the acceleration a .

$$a = g \sin \theta$$

If θ is known and a is determined experimentally, then provides an experimental value for g .



Procedure

- 1) Level the air table by means of the three adjustable legs until a puck placed near the center of the table is essentially motionless.
- 2) Place a small block under the air table single leg to make the table act as an inclined plane. The angle of the inclined plane is determined by the distance between the air table legs ' d ' and the height ' h ' of the block placed under one leg.
- 3) Set the sparktimer to a spark rate of 100 msec. This will produce a spark every 0.100 seconds.
- 4) Place a piece of carbon paper and a sheet of recording paper on the air table with the recording paper on top.
- 5) Place the two pucks on the table. To complete the circuit, both pucks must be attached to the sparktimer, but one puck can be left at rest at the bottom of the

inclined plane. Simultaneously start the sparktimer and release the other puck from rest at the top of the inclined plane. Allow the puck to accelerate down the incline while the sparktimer is in operation, but stop the sparktimer as the puck hits the bottom rail. Release the puck with no initial velocity. Do not impart any sideways motion to the puck when releasing it.

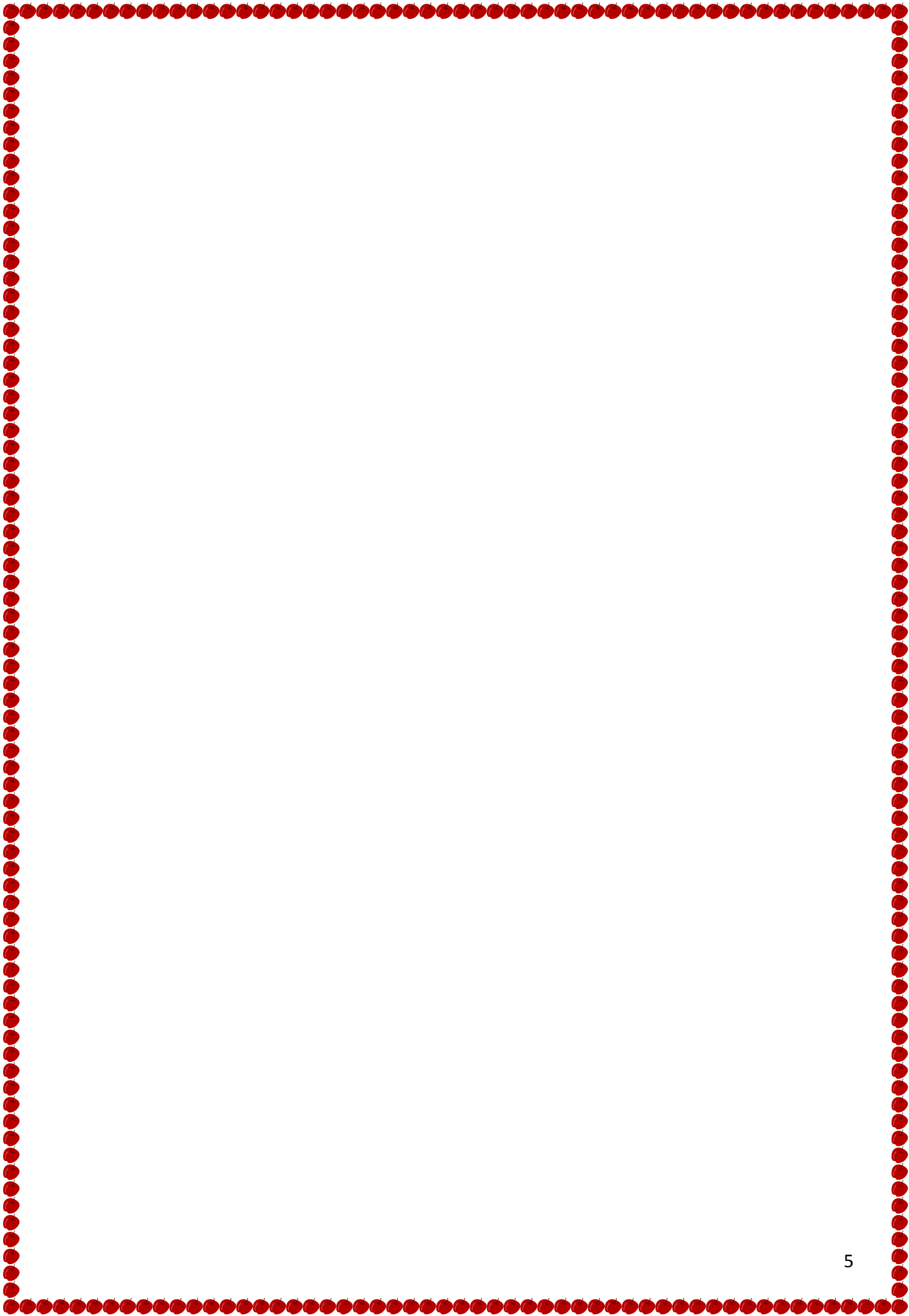
- 6) Choose a point near the beginning of the track as the origin and label it as $x_0=0$. Call the corresponding time $t_0=0$. Measure to the distance between the origin and the other points as a function of time, record your result in the table for 12 data points. For each data point, the coordinate x is to be measured from the origin to that point.
- 7) calculate the average velocity during each time interval from the values of Δx_n and the value of Δt_n . The average velocity for each interval is equal to the instantaneous velocity v_n at the middle of that interval. Record the instantaneous velocity v_n at the time each velocity occurs in the Calculations Table.

$$v_n = \frac{\Delta x_n}{\Delta t_n} = \frac{x_{n+1} - x_{n-1}}{t_{n+1} - t_{n-1}}$$

- 8) Make a graph of position against time $x = v_0 t + \frac{1}{2} a t^2$, use the graph to determine initial velocity v_0 .
- 9) Make a graph of instantaneous velocity v_n against time $v = v_0 + a t$, use the graph to determine the initial velocity v_0 and acceleration a . Compute the acceleration of gravity g ,

$$g = \frac{a}{\sin \theta} = \frac{a d}{h}$$

n	0	1	2	3	4	5	6	7	8	9	10
$t_n(s)$											
$x_n(cm)$											
$\Delta x_n(cm)$											
$v_n(cm/s)$											



Experiment No. (12)

Two-dimensional Motion Projectile Motion

Objective

To demonstrate the independence of motion along two perpendicular axes in projectile motion.

Theory

If an object is launched at an angle θ above the horizontal, the resulting two-dimensional motion can be resolved into two independent motions: accelerated motion along the vertical (y-axis) and uniform motion (constant velocity) along the horizontal (x-axis). We summarize our description of projectile motion:

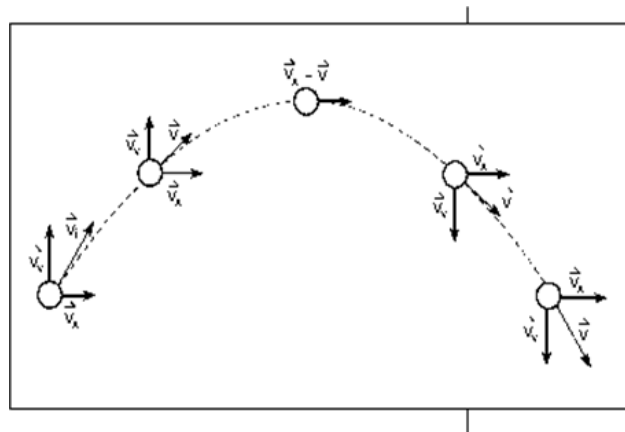


Figure (12-1): Projectile Motion

Free falling motion along the y-axis:

$$v_y = v_{0y} - gt, \quad (1)$$

$$y = v_{0y}t - \frac{1}{2}gt^2, \quad (2)$$

$$v_y^2 = v_{0y}^2 - 2gy. \quad (3)$$

Uniform motion along the x-axis:

$$v_x = \text{constant}, \quad (4)$$

$$x = v_x t, \quad (5)$$

$$a_x = 0. \quad (6)$$

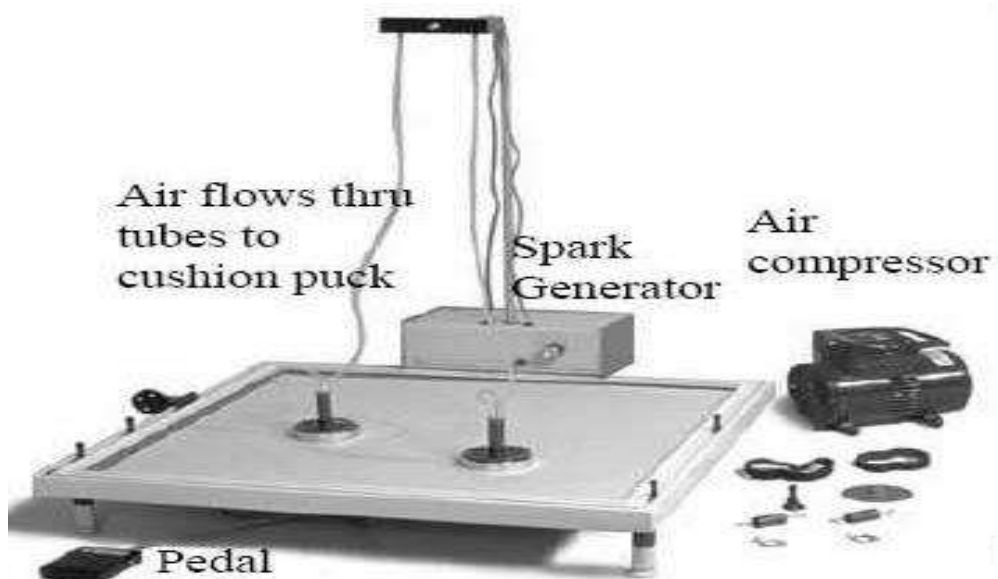
where $v_{0x} = v_x = v_0 \cos \theta$, $v_{0y} = v_0 \sin \theta$,

Experimental Details

To study projectile (two-dimensional) motion, the puck is launched at an angle θ . The x- and y- components of the displacement and velocity vectors are experimentally obtained from the spark marks left by the puck. The vertical (y) component of the velocity is obtained and used to experimentally determine the acceleration along the y-axis. The horizontal (x) component of the velocity for each position is measured.

Apparatus

Air Table with 2- air pucks, Air compressor, Ruler, Protractor.



Procedure

- 1) Lay down the sheet of carbon paper provided on the air table. On top of this put a new sheet of white paper provided. Since you will use only 1 puck for this experiment, set aside the other puck on a corner of the air table. Plug in

the air compressor power cord to begin supplying air used to cushion the pucks. Notice that the air puck now moves relatively freely along the surface.

- 2) Incline the air table at an angle ϕ with respect to the horizontal.
- 3) Set the frequency of the spark generator to $f = 80$ Hz (makes a mark every 1/20 second).
- 4) Launching the puck upwards at an angle θ from one of the lower corners of the table parabolic trace was produced.
- 5) The average velocity for each spark point were calculated from the displacements ($v = \Delta r / \Delta t$), then we can calculate $v_{xn} = \frac{\Delta x_n}{\Delta t_n}$, and $v_{yn} = \frac{\Delta y_n}{\Delta t_n}$
- 6) Graphs of x as a function of elapsed time. It is clear from this data that both x vary linearly with respect to time. Calculate the slope we obtain v_x .
- 7) Graphs of v_y as a function of elapsed time. It is clear from this data that both v_y vary linearly with respect to time. Calculate the slope we obtain a_y .
- 8) Finally, to find a value for g , the acceleration due to gravity,

$$a_y = -g \sin \phi, \quad (7)$$

- 9) with $\sin \phi = h/d$, substituting this expression in equation (7) results

$$g = -a_y \frac{d}{h} \quad (8)$$

n	0	1	2	3	4	5	6	7	8	9	10
t(s)											
x(cm)											
v_x (cm/s)											
y(cm)											
v_y (cm/s)											

$H_{\max}(\text{calculated}) = \dots\dots\dots$

$H_{\max}(\text{measured}) = \dots\dots\dots$

Range(calculated) = $\dots\dots\dots$

Range(measured) = $\dots\dots\dots$

$g = \dots\dots\dots$

$v_0 = \dots\dots\dots$

Experiment No. (13) Newton's Second Law

Objective

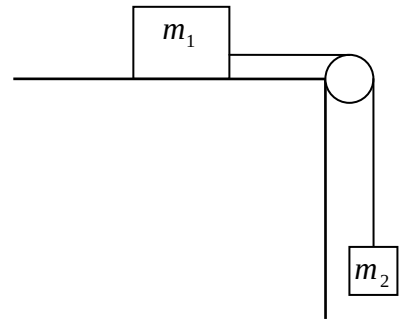
To make measurements that test Newton's second law of mechanics. A mass is accelerated along an air table by the weight of another "hanging" mass. The acceleration is measured and compared with that predicted by using Newton's second law of motion.

Theory

From Newton's second law the force acting on an (inertial) object equals the product of object's mass and acceleration,

$$\sum \vec{F} = m \vec{a} \quad (1)$$

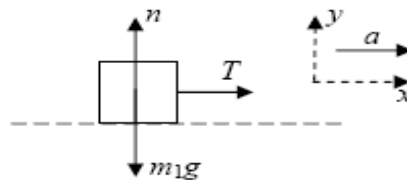
Consider a system of masses m_1 placed on a frictionless, horizontal table is connected to a cable that passes over a pulley and then is fastened to a hanging m_2 . Since we can neglect the masses of the string and the pulley, and the pulley is frictionless the tension at both ends of the string are the same (magnitude T). Let us assume m_2 accelerates downward with magnitude a . Since the two things are connected by the cable the acceleration of m_1 also has magnitude a , but is to the right.



FBD for m_1 :

$$\sum F_x = T = m_1 a_x = m_1 a \quad (2)$$

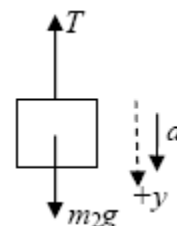
$$\sum F_y = n - m_1 g = m_1 a_y = 0 \quad (3)$$



Similarly FBD for m_2 :

$$\sum F_y = m_2 g - T = m_2 a_y = m_2 a \quad (4)$$

Inserting equation (2) into equation (4)



$$m_2 g = m_1 a + m_2 a \quad (5)$$

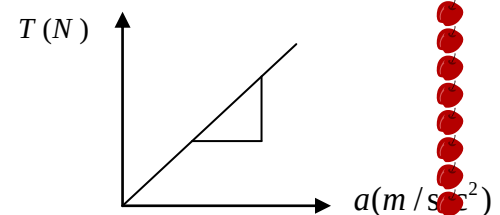
$$a = \frac{m_2 g}{m_1 + m_2} \quad (6)$$

Procedure:

- 1) Make sure that the air table is as level as is possible.
- 2) Attach one end of a string to the puck (mass m_1) . Run the string over the pulley and attach the other end to a hanging mass m_2 .
- 3) Turn on the sparker power supply and set the spark timer to 20 Hz. Do not at this time depress the sparker pad.
- 4) Hold the movable puck at rest with an insulator, such as a rolled up piece of writing paper, to avoid electrical shock.
- 5) Start the sparker by depressing the sparker pad and release the puck.
- 6) Observe the puck's motion and release the sparker pad before the puck reaches the far edge of the table to avoid spark trajectory bounce.
- 7) The average velocity for each spark point were calculated from

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

- 9) Determine the acceleration of the system from the graph of v as a function of elapsed time t .



- 10) Repeat the measurement of acceleration for different masses, and Determine the acceleration of the system for each mass.
- 11) Determine the tension T in the string for each mass from equation (4).
- 12) Plot the relation between the tension force T and the acceleration of different masses, we can determine the mass of the puck m_1 .

$$slope = \frac{\Delta T}{\Delta a} = m_1$$

n	1	2	3	4	5	6	7	8	9	10	11	12
$t(s)$												
$x(cm)$												
$v(cm/s)$												

hanging mass $m(kg)$	acceleration $a(m/sec^2)$	tension force $T(N)$

Experiment No (5)

FRICTION

Objectives:

To study the static and dynamic frictional forces, and to determine their coefficients.

Theory:

Friction is the most common force other than gravity. It requires a force to drag a body along a surface even though the surface is horizontal so that there is no resisting force due to gravity.

There are two types of frictional force: that when the body is at rest and that when the body is in motion. The static frictional force is defined as the resisting force encountered when one tries to slide one surface over another while keeping both surfaces at rest with respect to each other. The kinetic frictional force is defined as the resisting force between the two surfaces after they slide relative to each other.

It is experimentally found that the static friction F_s is proportional to the normal force N pressing the two surfaces together,

$$F_s \leq \mu_s N,$$

where μ_s is the coefficient of static friction.

A similar relation holds when the two surfaces are actually sliding relative to each other, in this case the kinetic frictional force F_k is given by :

$$F_k = \mu_k N,$$

Where μ_k is the kinetic coefficient of friction.

The normal force N can be calculated as follows:

If the body rests on a horizontal plane and the tension is horizontal as in Fig (5-a), then:

$$N = mg$$

If the body rests on an inclined plane as in fig (5-b) and the tension is parallel to the inclined plane, then:

$$N = mg \cos \theta$$

If $T=0$ and the body is about to slide then you can show that:

$$\mu_s = \tan \theta$$

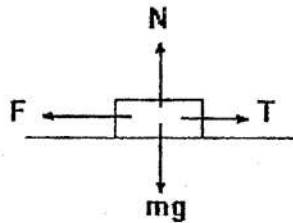


Fig. 5-a

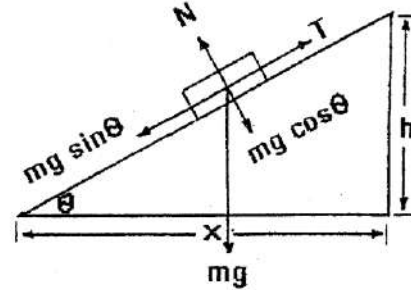


Fig. 5-b

Procedure:

[5-a] : Coefficient of static friction:

- 1) Place the wooden block on the top of the plane and increase the angle of inclination of the plane gradually.
- 2) When the block just starts to move, fix the plane at that angle. Measure the altitude h and the horizontal distance x .
- 3) Change the position of the wooden block and repeat paragraph 1 and 2.
- 4) Draw the relation between h as y-axis then find the slope of the obtained line (slope = $\tan \theta = \mu_s$).

h (cm)				
x (cm)				

[5-b] : Coefficient of kinetic friction:

- 1) Place the wooden block on the top of the inclined plane [angle of inclination = 16°]
- 2) Determine the time, t , that the wooden block will travel distance, d .

- 3) Repeat paragraph 2 many times for the same distance d.
- 4) Find the average time, T, and calculate the acceleration of the block

$$d = \frac{1}{2}aT^2$$

- 5) Coefficient of kinetic friction is given by:

Experiment No (7)

MOMENT OF INERTIA

Measurement of moment of inertia of a fly wheel:

If the end of a string is fixed in a hole of the axle of a fly wheel so that a mass m is suspended in the end of the string at a distance h cm above the floor and the mass be allowed to fall, it will lose its potential energy, see figure (7-a).

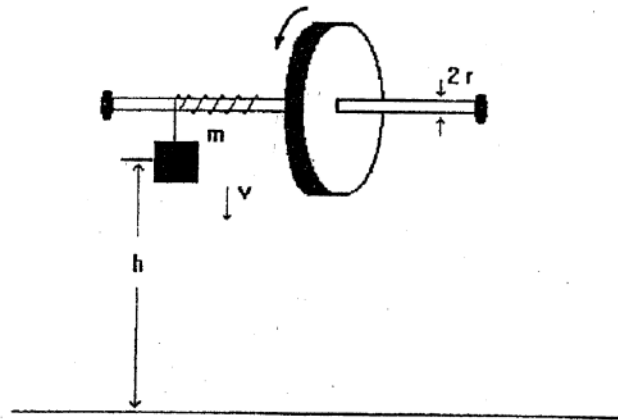


Fig. (7-a)

The potential energy lost will be converted into kinetic energy acquired by the falling mass, kinetic energy of rotation of the fly wheel, and into work done against friction when the wheel revolves, i.e.:

$$m g h = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 + n_1 f \quad (1)$$

where:

v : The velocity of the falling mass touches the floor.

ω : The angular velocity of the wheel when the mass touches the floor.

I : The moment of inertia of the wheel.

f : The work done against friction per one revolution.

n_1 : The number of revolutions before the mass touches the floor.

Let n_2 and t be the number of revolutions and the corresponding time after the string has been detached until the wheel come to rest.

$$\frac{1}{2} I \omega^2 = n_2 f$$

hence

$$f = \frac{1}{2} I \omega^2 / n_2 \quad (2)$$

But

$$v = r \omega \quad (3)$$

Where r is the radius of the wheel axle. Using equations (1), (2) and (3) we get

$$m g h = \frac{1}{2} m r^2 \omega^2 + \frac{1}{2} I \omega^2 \left[1 + \frac{n_1}{n_2} \right] \quad (4)$$

To determine the value of ω , we calculate the average angular velocity, which is:

$$\omega_{ave.} = \frac{(\omega + 0)}{2} = \frac{2\pi}{T_{ave.}} \quad (5)$$

But $T_{ave.} = t / n_2$

$$\omega_{ave.} = \frac{(\omega + 0)}{2} = 2\pi \frac{n_2}{t} \quad (6)$$

i.e. $\omega = \frac{4\pi n_2}{t} \quad (7)$

Apparatus:

A fly wheel, masses, a string and a stop watch.

Procedure :

- 1) Fix one of end of the string into the axle and turn it around such that when the suspended mass at the other end of the string reaches the floor, the string becomes detached from the axle (so it allows the wheel to revolve freely).
- 2) Record the number of revolutions, n_1 during the falling of the mass.
- 3) Record the time, t , and number of revolutions after the string had been detached until the wheel comes to rest.
- 4) Calculate the angular velocity, ω , from equation (7).

5) Knowing m , h , n_2 , r , and ω substituting these values in equation (4), the moment inertia, I , can be determined.

Results :

h =-----, r =-----

m (g)				
$n1$ (rev.)				
t (sec)				
n_2 (rev.)				
ω (rad/sec)				
I (g.cm ²)				

Then $I_{average}$ = -----

Experiment No (8)

PERIODIC MOTION

The motion of a particle is said to be periodic if the same series of movements is repeated at regular intervals of time. The period of this motion is the time required for complete cycle. The number of such cycles in one second is called the frequency of motion.

The Simple Pendulum:

It consists of heavy body (bob) suspended from a fixed point by means of weightless and flexible string, as shown in fig. (8-a). If the bob is displaced to one side and is let free, it begins to vibrate to-and-fro about its position at rest, (o). The maximum distance traveled either to right (ob) or to the left (oc) is called the amplitude. The motion of the bob from o to b then to o to c then to o again is considered as one complete cycle. The time taken during one complete cycle is related to the length L of the pendulum and can be derived as follows:

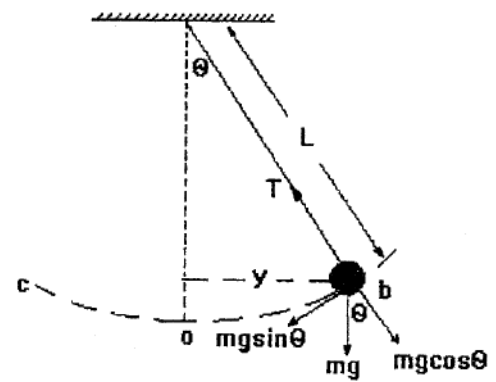


Fig. (8-a)

From the figure shown the component that makes the body to oscillate is $(m g \sin \theta)$ and according to Newton's second law:

$$F = m a = - m g \sin \theta \quad (1)$$

The minus sign indicates that the displacement (y) decreases as (a) increases.

But $\sin \theta = y/L$ (where θ is very small) (2)

Thus $a = -\frac{g}{L} y = -(g/L)y$ (3)

This motion is a S.H.M. since the acceleration is directly proportional to the minus displacement and can be written as:

$$\frac{d^2 y}{d t^2} = -\omega^2 y \quad (4)$$

where $\omega^2 = g/L$ and ω is called the angular velocity.

But
$$\omega = \frac{2\pi}{T} \quad (5)$$

where T is the periodic time.

Then
$$\frac{4\pi^2}{T^2} = \frac{g}{L} \quad \text{or} \quad T^2 = \frac{4\pi^2}{g} L \quad (6)$$

Or
$$T = 2\pi \sqrt{\frac{L}{g}} \quad (7)$$

Apparatus:

A simple pendulum, a stopwatch, a meter stick and vernier caliper.

Procedure :

Let the bob to vibrate (the motion should not be elliptical or circular).

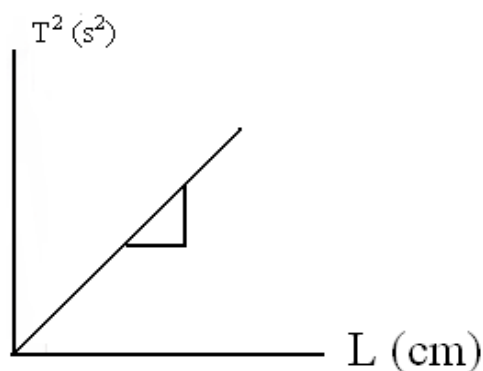
Record the time for 20 cycles using a suitable length for the string then calculate the time for one cycle.

Record the time for the same number of cycle for different lengths L, with increments about 10 cm and calculate time T, for one cycle each time.

Draw the relation between L as x-axis and T² as y-axis.

Determine the slope of the straight line obtained and calculate the gravity acceleration, (g).

$$\text{slope} = \frac{4\pi}{g} \quad (8)$$



Results :

Put the results in the table as follows:

bob radius (r) = -----

L(cm) (includes bob radius)	Time for 20 cycles (sec)	Time for one cycle (T) (sec)	(T ²) (sec ²)

Connect two spring as show in Fig.5 .

Repeat all the steps in part (III- a) to find K_{total} measured and calculated for two parallel springs.

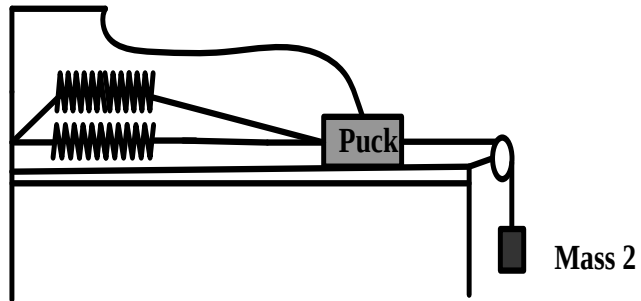


Figure 5. Two spring are connected in parallel on air table.

Mass (gm)	X_i (cm)	X_f (cm)	L' (cm)
1-			
2-			
3-			

Experiment No (9)

ELASTICITY AND HOOK'S LAW

A solid has definite volume and a definite shape. The shape of a solid can only be changed under the effect of a force either by stretching or compression. Hence, if a vertically mounted rod, wire or spring is supported rigidly at its upper end, and weights are added to its lower end then the amount by which it is stretched is found to be proportional to the weights applied. The rod, wire or spring is said to be perfectly elastic if it retains its original shape and volume after the removal of weights.

Hook's Law:

Hook's law states that the deformation of an elastic body is directly proportional to the magnitude of the applied force, provided that the elastic limit is not exceeded.

Theory:

When a weight is suspended from the end of a spring, experiments show that the elongation in the spring is proportional to the weight (If the elastic limit is not exceeded).

Then, $\text{Elongation (L)} \propto \text{Force (F)}$ (1)

If the spring is affected only by the suspended object and the effective mass of the spring then,

$$F = m g \quad (2)$$

where m is the mass and g is the acceleration of gravity.

From (2) in (1)

$$L \propto m g \quad (3)$$

$$\text{Or} \quad m g = k L \quad (4)$$

where k is the elasticity constant of the spring and has the unit (dyne/cm).

If the spring is pulled down to a small distance x and then released, it will oscillate about the position of equilibrium then its equation will be

$$m a = -[k (L + x) - m g] \quad (5)$$

but from (4), $(m g = k L)$

$$m a = -k x \quad (6)$$

$$a = -(k x) / m \quad (7)$$

$$a = \frac{d^2 x}{d t^2} = -\frac{k}{m} x \quad (8)$$

$$\frac{d^2 x}{d t^2} = -\frac{k}{m} x \quad (9)$$

this is a S.H.M. equation such as

$$\frac{d^2 x}{d t^2} = -\omega^2 x \quad (10)$$

where

$$\omega^2 = k / m \quad (11)$$

(ω is called the angular velocity) where ω is equal to $2\pi/T$ (T is the periodic time)

$$(2\pi/T)^2 = k / m \quad (12)$$

$$T^2 = 4\pi^2 m / k \quad (13)$$

which gives

$$T = 2\pi \sqrt{m/k} \quad (14)$$

$$\text{but } m = m_0 + m' \quad (15)$$

where m_0 is the effective mass of the spring ($m_0 = 1/3$ mass of the spring) and m' is the mass used and we can find from (4) that, $m_0 g = k L_0$ (16)

where L_0 is the effective length, and from (15) in (14)

$$T^2 = 4\pi^2 \left(\frac{m}{k} \right) = \frac{4\pi^2 m_0}{k} + \frac{4\pi^2 m'}{k} \quad (17)$$

and from equation (4) we can find another relation

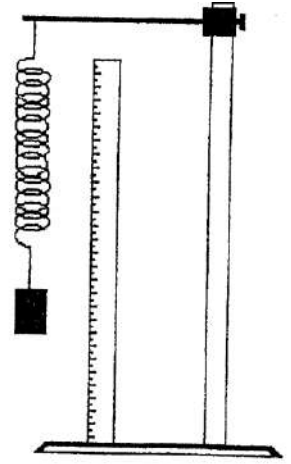


Fig. 9-a

$$mg = k L$$

$$m / k = L / g \quad (18)$$

and from (14) and (18)

$$T = 2\pi\sqrt{L / g} \quad (19)$$

$$\text{but} \quad L = L_0 + L' \quad (20)$$

$$T^2 = 4\pi^2 \left(\frac{L_0 + L'}{g} \right) \quad (21)$$

$$T^2 = \frac{4\pi^2}{g} L_0 + \frac{4\pi^2}{g} L' \quad (22)$$

Apparatus:

Spring, weights, a meter stick, and a stop watch.

Procedure:

- 1) Determine the initial reading on the scale when no weights put in the pan.
- 2) Add different weights (m') and find the corresponding scale reading.
- 3) Determine the elongation L' (cm) in the spring.
- 4) Pull the pan down a small distance such that it makes a small oscillation about the equilibrium position and record the time, in seconds, for 20 oscillations then find the time for one oscillation.
- 5) Repeat steps (2, 3, and 4) for different weights.
- 6) Plot T^2 on the y-axis and L' on the x-axis, $T^2 = (4\pi^2 / g)L'$.
- 7) Determine the slope of the straight line obtained then find the gravity acceleration ($\text{slope} = 4\pi^2 / g$).
- 8) Plot the relation between T^2 as y-axis and m' as x-axis. Find the slope and then find the constant k from the slope.
- 9) Plot the mass m' on the y-axis and L' on the x-axis and find k .

Results:

Mass m' (gm)						
Elongation L' (cm)						
Time(T)for 20 osc.						
Time(T) for 1 osc.						
T^2 (sec ²)						

