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دولـــة فلســـطين

وزارة التعليـم العــالي والبحـث العلمي

State of Palestine

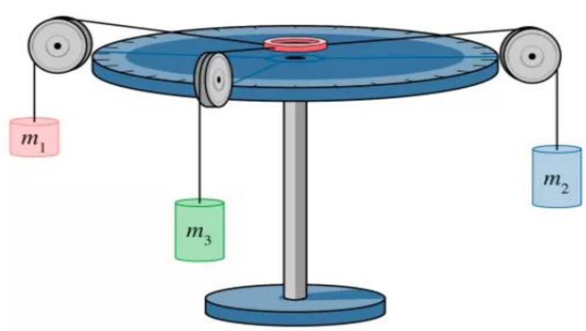
Ministry of Higher Education & Scientific Research

Physics Department

Faculty of Applied Sciences-Palestine Technical University-Kadoorie

Laboratory Manual

General Physics Lab. I



Prepared by

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General Physics Lab. I No. 15020105

General Remarks:

The laboratory manual is designed for physics experiments concerning mechanics and motion and is closely correlated with the material covered by the lectures of the General Physics Course I. It helps to guide the 1st year students in performing the experiments. The first part of each experiment is designed to give a complete discussion, including the main ideas, concepts, experimental apparatus, and technique needed to experiment, the 2nd part is an attached paper of the experimental report, which has to be filled and completed by the student. This lab course aims to provide the students with a realistic experience; how to practice physics in reality and enjoy the beautiful mutual interaction between theory and experiment, since all physical concepts and relationships introduced in the lectures of the course describe the behavior of real natural phenomena. It is so oriented to supply the students with the essential platform to do physics by hand and gain knowledge through direct observations and measurements. So it is expected to increase the student's understanding and tools ability in physics including experimental techniques, result manipulation, and data analysis.

Students have to prepare themselves before coming to the laboratory. Two students will do the same experiment as a group, but each student has to write the report and perform the analysis independently.

Experiment	Experiment Title	page
1	Measurements and Error Analysis	3
2	Vectors – Forces	8
3	Acceleration on an Inclined Plane	13
4	Newton's 2nd Law	17
5	Friction	20
6	Uniform Acceleration Motion	26
7	Atwood's Machine	29
8	Conservation of Energy	32
9	Conservation of Linear Momentum	35
10	Pendulum	40
11	Coefficient of viscosity	45

Experiment No. 1
Measurements and Uncertainties

Objectives:

(1) Learn to use Vernier Caliper and micrometer to measure lengths.
(2) Make some elementary measurements of lengths and mass and derive other quantities, from them such as the value of π , volume V and density ρ.
(3) Determine the uncertainty or the experimental error for both the measured and calculated quantities.

Equipment:

Meter stick, micrometer, vernier caliper, electric balance, iron spheres, iron cylinders, irregular iron pieces, circular, spherical, and cylindrical wooden pieces.

Theory:

Any experimental measurement or result has an uncertainty associated with it. In today's lab, you will perform a set of very simple measurements and estimate the uncertainty associated with each of them. Then you will do some calculations using the values you just measured. The results of those calculations will also have an uncertainty associated with them.

The uncertainty- measures how far an experimental quantity might be from the "true value", the same as the accuracy. Accuracy – indicates how close a measurement is to the actual or expected known value. The Precision – shows how close a set of measurements are to one another.

The experimental error – is the difference between the actual or expected value, and the measured value. The standard error is the absolute uncertainty of the average value.

To reduce experimental errors and uncertainties of a calculated quantity it is useful to perform the measurement several times changing the measured parameters and finding the mean value or the average of the calculated quantity $\overline{R}$ defined as:

$$\overline{R} = \sum_{i}^{N} \frac{R_i}{N} \quad (R_i \textit{ the result for each trial, and N is the number of trials})$$

The uncertainty is then obtained from the STANDARD ERROR, or the absolute uncertainty of the average value, i.e. the standard deviation given by:

$$\Delta\overline{R} = \sqrt{\frac{\sum_{i}^{N} \left(R_i - \overline{R}\right)^2}{N(N-1)}}, \quad d_i = R_i - \overline{R}$$ measures the deviation of each result from the mean.

Another way to obtain the best value of a calculated quantity is to make graphs or plots, when the relation between variable y and x is linear and the equation is represented by a straight line which is given by:

$$y = ax + b$$

Where: a is the slope of the line, b is its y-intercept (x=0) when x is the independent variable and y is the dependent variable. If the line passes through the origin (x=0,y=0),

$$y = ax.$$

In this experiment, you will learn how to use some measuring instruments, a ruler, vernier caliper, and micrometer to measure lengths and digital balance to measure mass, and to calculate some constant quantities such as the value of π and density ρ from the measured quantities. You will also learn to express experimental errors in the form of uncertainties, which is the smallest the smallest division of the graduated scale of the measuring device and standard deviation or the error in the mean of multiple values of data, and the percentage error which measures how one is close from the true accepted value.

For any round object, the circumference c is directly proportional to its diameter d, such that:

$$c = \pi d$$

Where π is constant. By measuring the values of c and d for many round objects one can determine the value of $\bar{\pi}$ as the mean value of the individual values of π, or by plotting the values of c versus d, one can obtain the slope of the curve to be the best value of π

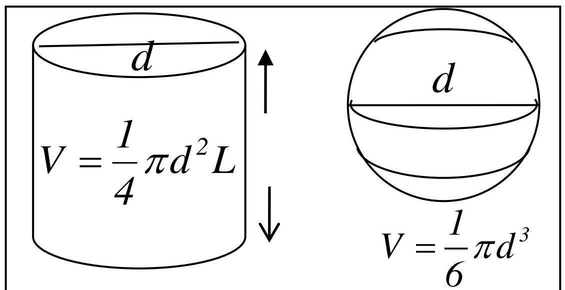


Fig.1.1: Volume of a sphere and Cylinder

For an object of any material, the density ρ is defined as the ratio of the mass m to its volume V.

$$\rho = \frac{M}{V}$$

For a sphere of radius r the volume is given by (Fig.1.1),

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{1}{6}\pi d^3$$ d being the sphere diameter.

For a cylinder, it is given by $V = \pi r^2 L = \pi\left(\frac{d}{2}\right)^2 L = \frac{1}{4}\pi d^2 L$,

Where r is the radius of its base, d is the diameter, and L is the height of the cylinder.
For irregular objects, one finds V by measuring the size of water displaced by the object, measuring m, and calculating the density ρ.

Procedure:

(I) Measure the circumference of a given round object (wooden cylinder) using a paper strip and the meter ruler.

(2) Measure the diameter of the round object using the vernier caliper and record your measurements in Table 1 of the report sheet. (See 1.2)

(3) Calculate the value of π each measurement, its mean value $\bar{\pi}$, and its error $\Delta\bar{\pi}$, as stated in the sheet.

(4) Plot c vs. d, determine the slope and then calculate the percentage error for this value of slope which $= \pi$.

(5) Measure the diameter d of a rod cylinder using the micrometer.

(6) Measure the height (length) L of the cylinder using the vernier caliper.

(7) Determine the masse m and calculate the density ρ for your iron piece.

(8) Calculate the density ρ and its uncertainty $\Delta\rho$.

$\rho = \dfrac{M}{V}$	Where V is the volume is given by,
$V = \dfrac{1}{6}\pi d^3$ *(sphere)*	$V = \dfrac{1}{4}\pi d^2 L$ *(cylinder)*

And the uncertainty $\Delta\rho = \rho\left[\dfrac{\Delta m}{m} + \dfrac{\Delta V}{V}\right]$

$$\Delta\rho = \rho\left[\frac{\Delta m}{m} + \frac{2\Delta d}{d} + \frac{\Delta L}{L}\right],$$ for cylindrical shape.

$$\Delta\rho = \rho\left[\frac{\Delta m}{m} + \frac{3\Delta d}{d}\right] = \rho\left[\frac{\Delta m}{m} + \frac{3\Delta r}{r}\right],$$ for spherical shape.

Compare your result with the true value of the density of the cylinder.

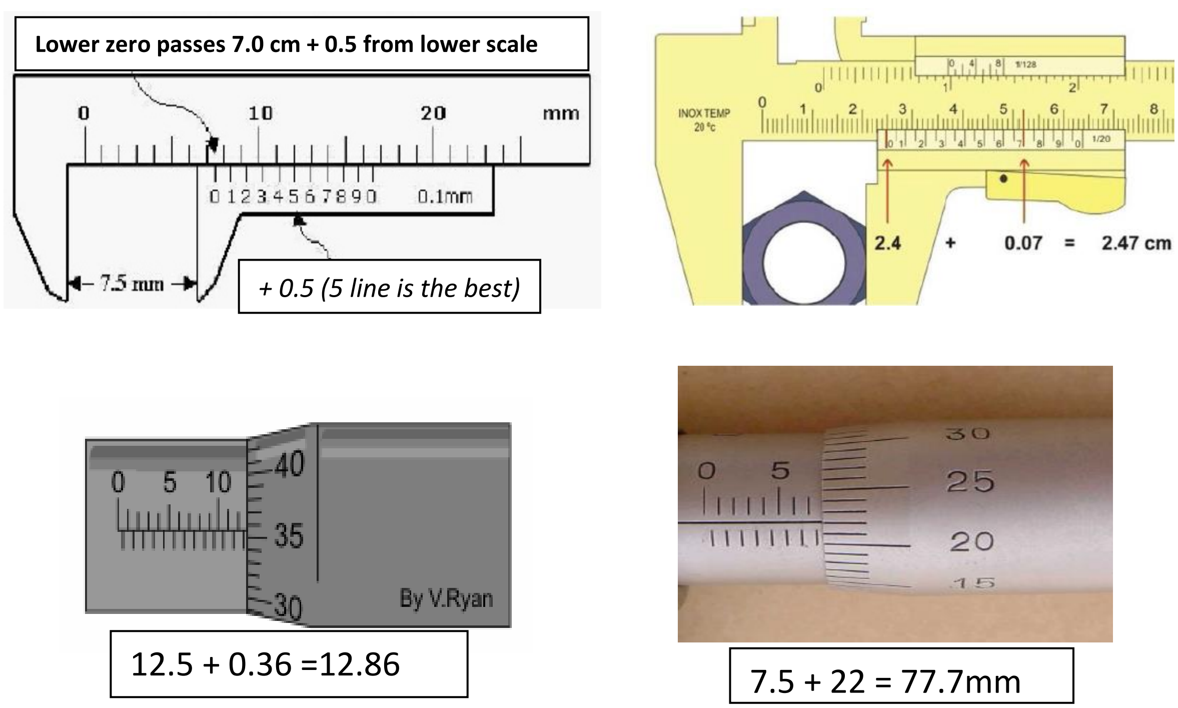


Fig.1.2: Readings of Vernier and Micrometer

Exp. No. 1

Measurements

Name: …………………………………………………….………….. Grade: …...............................

Student's No.: ………………………………………....... Day and Date: …………………………

Partner's Names: ……………………………………………………….. Sec.: …………………

Part I: Data and Calculation:

No. of trails	**Circumference c(cm)**	**Diameter d(cm)**	$\pi = c/d$	**Deviation** $d_i = \pi_i - \bar{\pi}$	d_i^2
Mean Value $\bar{\pi}$ **=**			$\sum_{i=1}^{N} d_i^2$ **=**		

(1) Calculate the value of π for each measurement.

(2) Calculate the average or the mean value $\bar{\pi}$.

(3) Calculate the deviation of each value from its mean $d_i = \pi_i - \bar{\pi}$.

(4) Calculate d_i^2 and $\sum_{i=1}^{N} d_i^2$

(5) Tabulate your results in Table 1.

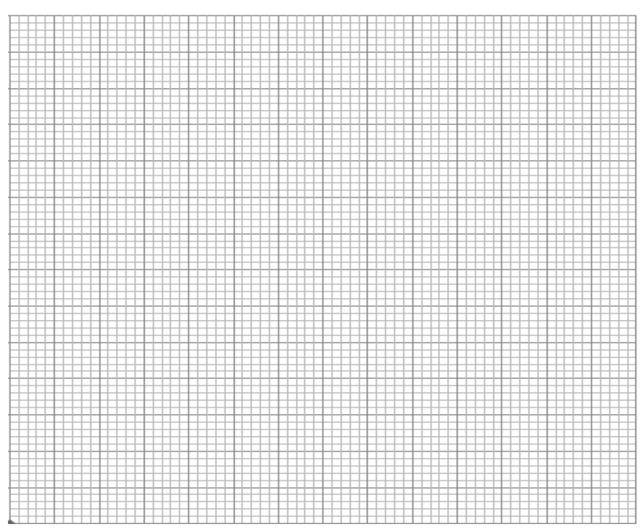
(6)Calculate the error in the mean $\Delta\bar{\pi}$

(Standard error)

$$\Delta\bar{\pi} = \sqrt{\frac{\sum_{i}^{n} (d_i)^2}{N(N-1)}}$$

(7) Plot a graph between c and d and determine the slope of this graph S.

(8) What does this slope represent?



(9) Calculate the percentage error in π giving the real value of $\pi = 3.143$.

Percentage error = $\frac{|\,measured\ value - true\ value\,|}{true\ value} \times 100\% =$

Part II: Measuring the Density of a cylindrical rod.

Object	Diameter	height	Mass	Volume	Density
	$d \pm \Delta d$ (cm)	$L \pm \Delta L$ (cm)	$m \pm \Delta m$ (gm)	$V \pm \Delta V$ (cm^3)	$\rho \pm \Delta\rho$ (gm/cm^3)
Cylinder					

Calculation:

The volume of the object = V =

ΔV =

Density ρ =

Δρ =

Derive the SI unit of density ρ.

Experiment No. 2
Vectors

Objective:

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

Apparatus:

Vector force table, Slotted weights and weight hangers, pulleys, and protractors.

Theory:

Vector quantities are physical quantities, which **have magnitude and direction.** Suppose we have two forces $\vec{F}_1$ $\vec{F}_2$ acting on an object as shown in Fig. 2.1. The two forces can be replaced by one force called the resultant force $\vec{R}$, which has the same effect as the two forces.

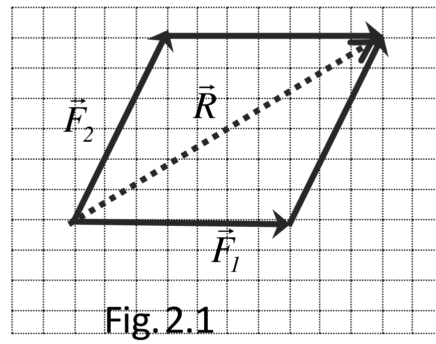


Fig. 2.1

$$\vec{R} = \vec{F}_1 + \vec{F}_2$$

The resultant Force can be found by different methods:

(1) Graphically (Polygon method) in this method, the forces as vectors are represented by rows in a head-to-tail fashion. Consider three forces $\vec{F}_1,\ \vec{F}_2\ and\ \vec{F}_3$.

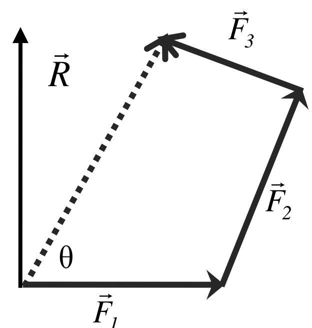


Fig. 2.2

The vector $\vec{R}$, which closes the diagram, is the resultant force. The length of each arrow represents the magnitude of the corresponding force, see (Fig. 2.2).

This is done by choosing a suitable scale. The tail of the second force is placed at the head of the first, and the angle of the second is measured with respect to the first, and so on. The resultant $\vec{R}$ joins the tail of the first to the head of the last. The angle ϕ represents the direction of $\vec{R}$ with respect to $\vec{F}_1$. For two the addition of two forces, the method is called the triangular method.

(2) The method of components:

Each force vector is resolved into horizontal (x) and vertical (y) components. For the resultant of two forces: $\vec{F}_2$

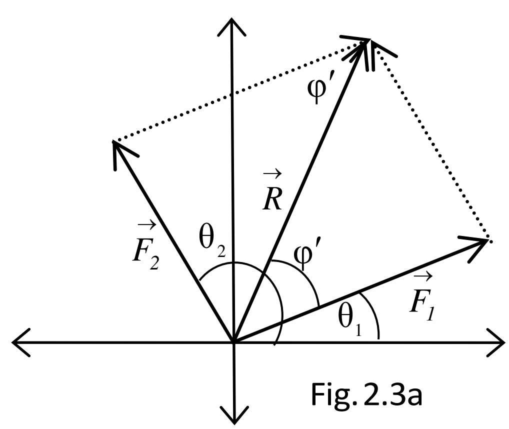


Fig. 2.3a

$$R_X = \sum_{i=1}^{2} F_i \cos\theta_i = F_1 \cos\theta_1 + F_2 \cos\theta_2$$

$$R_y = \sum_{i=1}^{2} F_i \sin\theta_i = F_1 \sin\theta_1 + F_2 \sin\theta_2$$

The magnitude $\vec{R}$ is given by (Fig.2.3a)

$\vec{R} = \sqrt{R_X^2 + R_y^2}$, and its direction is $\phi = tan^{-1}(\frac{F_y}{F_x})$

(3) Calculation method: the magnitude of the resultant $\vec{R}$ of the forces $\vec{F_1}$ and $\vec{F_2}$

$$\vec{R} = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos\theta}$$

Where θ is the angle between $\vec{F_1}$ and. The direction of $\vec{R}$ with respect to $\vec{F_1}$ is: (Fig.2.3a)

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

with respect to x $\phi = \phi' + \theta_1$

Or $\frac{\sin\varphi'}{F_2} = \frac{\sin(180-\theta)}{\vec{R}}$ (fig.2.3b)

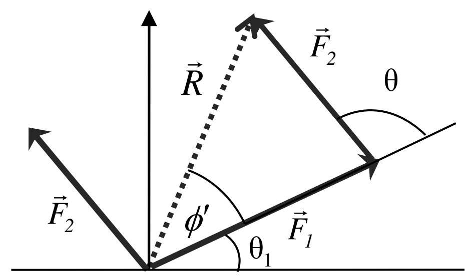


Fig. 2.3b

(4) Force table and Procedure:

(1) Use the adjustable screws of the three legs to level the force table horizontally.

(2) Hang three mass hangers with the strings passed over three pulleys clamped to the edge of the force table and attached to the ring around the pin at the center of the force table.

(3) Fix two pulleys for the two forces to be added $F_1 = m_1 g$ at an angle θ_1 and $F_2 = m_2 g$ at θ_2, the third pulley will be clamped for the *equilibrant force (opposite to the resultant)*,

(4) Estimate the angle of the third string by hand.

(5) Adjust the mass on the third hanger and the angle of its pulley to find the third equivalent equilibrant force that balances the other two forces and makes the pin at the center of the ring. Fig. 2.4

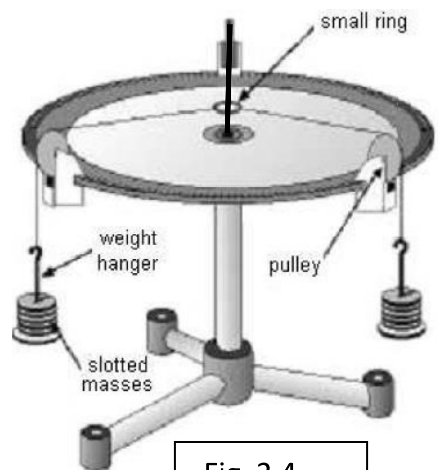


Fig. 2.4

(6) Determine the magnitude and angle of the equilibrant force $\vec{F_3} = -\vec{R}$ ($\phi_{\vec{R}} = \phi_{-\vec{R}} - 180^0$)

(7) Record the forces in terms of g, for example, if, $m_3 = 200\ gram$, then:

$F_3 = 200g$ dyne $(g = 980\ cm/s^2)$ or $F_3 = 0.2g$ **N** $(g = 9.8\ m/s^2)$

(8) Compute the resultant force:

a) Graphically

b) By the method of components,

c) By Calculation fill in the report below.

Exp. No. 2

Vectors

Name: ……………………………………………….………….. Grade: …...............................

Student's No.: ……………………………………........ Day and Date: …………………………

Partners Names: ……………………………………………..…... Sec.: …………………

Data:

(1) Use the force table to find the resultant R of two vector forces and fill the table below

Method	$\lvert F_1 \rvert$	$\lvert F_2 \rvert$	θ_1	θ_2	F_x	F_y	$\lvert R \rvert$	$\varnothing_R$	Error% In R
Force Table									
Calculation									
Components									
Graphically									

(2) Calculation:

Compute the resultant **R** (magnitude and direction) by direct calculation:

$R = \sqrt{\qquad\qquad\qquad\qquad\qquad\qquad}$ = ………….……………………………

$\phi' = tan^{-1} \dfrac{\qquad}{\qquad} =$ .... , $\phi =$ ....

(3) **<u>Find R graphically</u>** (triangle method) using graph paper.

From your drawing, determine:

R = ….................................

Ø = ...

(4) <u>Method of components:</u> Compute **R** by the method of components

F_x = ……………………………………………………………………………………………

F_y = ……………………………………………………………………………………………

R = ……………………………………………………………………………………………

$$\phi = tan^{-1}\left(\frac{\qquad}{}\right) =$$

(5) Find the **percentage error P.E.** for each case above.

$$PE = \frac{|\ measured\ value - true\ value\ |}{true\ value} \times 100\%$$ (the true value of R is calculated in 1)

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(6) Add the following two vectors: $\vec{u} = 1\hat{i} + 2\hat{j}$, $\vec{v} = 2\hat{i} - 5\hat{j}$

…………………………………………………………………………………………………

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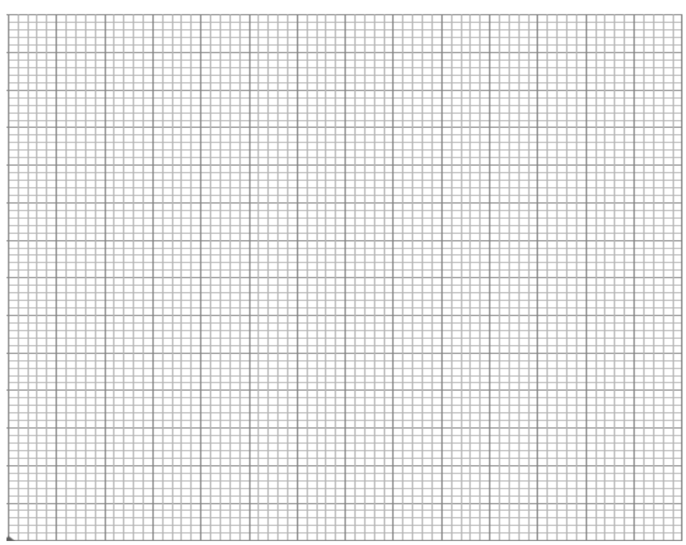
(7) Draw the two vectors described above and add them graphically (i.e. find the resultant)



(8) Split the 3 vectors drawn below into the two given (x,y) components and add them up.

A$_x$ = ……………………………………………

A$_y$ = ……………………………………………

B$_x$ = ……………………………………………

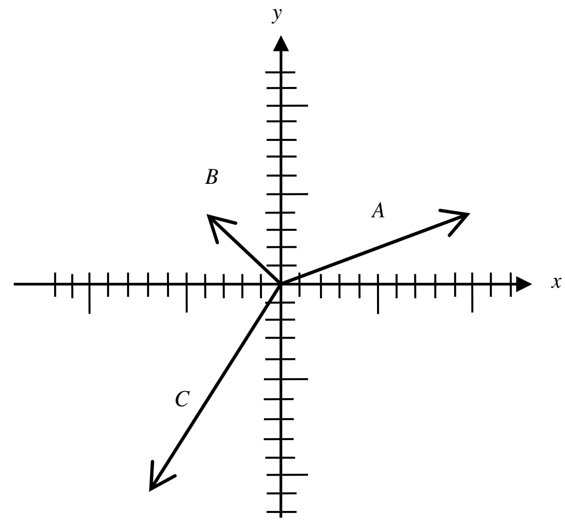
B$_y$ = ……………………………………………

C$_x$ = ……………………………………………

C$_y$ = ……………………………………………

R$_x$ = ……………………………………………

R$_x$ = ……………………………………………



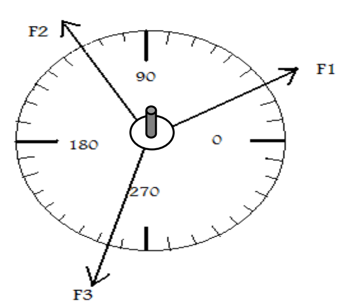
$\vec{A} = (\quad)\,\hat{i} + (\quad)\,\hat{j}$,

$\vec{B} = (\quad)\,\hat{i} + (\quad)\,\hat{j}$

$\vec{C} = (\quad)\,\hat{i} + (\quad)\,\hat{j}$

$\vec{R} = (\quad)\,\hat{i} + (\quad)\,\hat{j}$

(9) In the adjacent Fig. the forces are in equilibrium **F**$_1$ = 80g dyn and **F**$_2$ = 60g dyn. Determine the resultant vector sum **R** of and its direction.



Experiment No. 3
Acceleration on Inclined Plane

1. Objectives:

(1) Study the relation between covered distance x and elapsed time t for the glider on an air track moving under constant acceleration.
(2) Determine the acceleration of the glider on the incline and then the acceleration due to gravity

2. Apparatus:

Air track, glider, ruler, air pump, timer with two photogates, spirit level.

3. Theory:

To determine the acceleration due to gravity (g) in physics lab (1), one uses an inclined frictionless plane (مستوى مائل أملس عديم الاحتكاك) (air track) with two light gates, a timer, and a glider. (See Fig. 3.1)

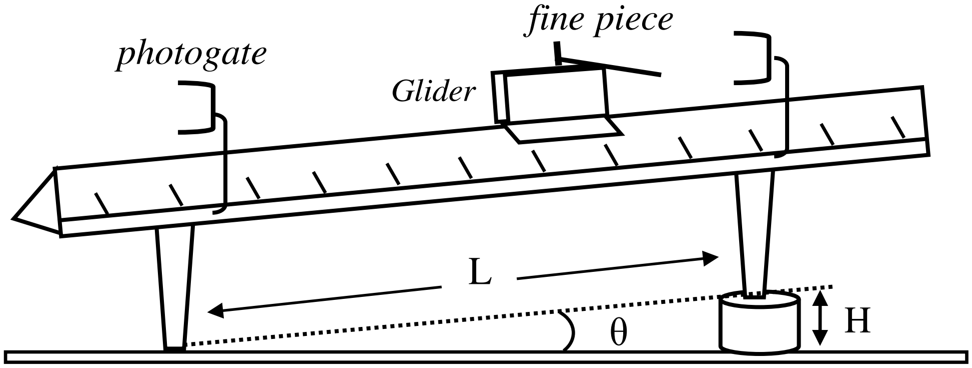
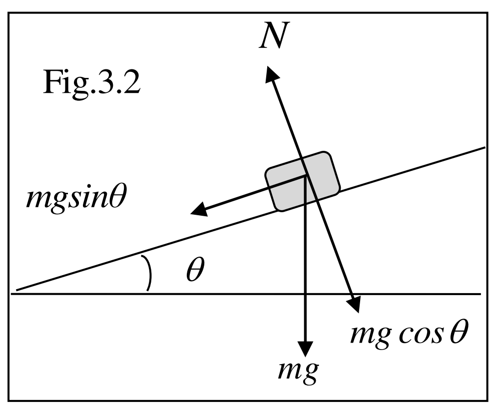


Fig.3.1 Air track inclined at angle θ

You will calculate the acceleration of a body on an inclined, near-frictionless plane (a glider on the air track) from measurements of distance and time, assuming the acceleration constant. This is the experimental acceleration. Then, from finding the angle of inclination of the track (using trigonometry), you will find the acceleration due to gravity g.



For the glider moving down the incline <u>from rest</u> is

$X = \frac{1}{2}at^2$, where X is the distance traveled, and t is the time needed by the glider to cover this distance.

From newton's 2nd law for the motion along the plane is (fig. 3.2)

$$ma = mgsin\theta$$

The acceleration of the glider is then

$$a = g\ sin\theta \qquad \Rightarrow g = \frac{a}{sin\theta}$$

If the distance traveled on the incline **x** is plotted vs. $\mathbf{t^2}$, the slope of the graph obtained is from (when the glider starts from rest)

$$X = \frac{1}{2}at^2 \qquad \Rightarrow slope = S = \frac{1}{2}a, \qquad a = 2S$$

Draw two best lines find the slopes as S_{max} and S_{min}

$$S = (S_{max} + S_{min})/2,$$
$$\Delta S = (S_{max} - S_{min})/2$$
$$slope = S = \frac{1}{2}a \qquad \Rightarrow a = 2S = g\ sin\theta$$

$$\Rightarrow \quad g = \frac{a}{sin\theta} = \frac{2S}{sin\theta}$$

$$\Rightarrow \quad \frac{\Delta g}{g} = \frac{\Delta S}{S} + \frac{\Delta sin\theta}{sin\theta}, \quad \text{and} \quad \frac{\Delta sin\theta}{sin\theta} = \frac{\Delta L}{L} + \frac{\Delta H}{H}$$

4. Procedure:

1) Level the air track horizontally with the leg screws by adjusting the screw until the glider does not accelerate in either direction along the track.
2) Make the air track inclined at an angle θ by putting a piece of wood at one end under the leg of the track.
3) Calculate $\sin\theta$ by measuring the hypotenuse and opposite. $\sin\theta = \frac{H}{L}$
4) Release the glider from the top end of the air track from rest and measure the time the glider needs to pass a specified distance x to the lower end.
5) Repeat 3 times measuring the time labeled t_1, t_2, and t_3 for the same distance.
6) Repeat the previous steps 5 times for different distances.
7) Tabulate your results in the table of the report.

Exp. No. 3

Acceleration on Inclined Plane

Name: ……………………………………………………….………….. Grade: …..............................

Student's No.: ……………………………………........ Day and Date: …………………………

Partners Names: …………….……………………………….……..……… Sec.: …………………

Data:

(1) Measure the sin of the inclination angle $\sin\theta = H / L =$

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

(1) For each value of X find the average time squared $\bar{t}^2$, and fill them in the table above.

(2) Plot the distance traveled **X versus** $\bar{t}^2$ and connect the points with the best two lines. **calculate the slope of each, call them** S_{max} **and** S_{min}

(4) Find S_{max} = ………………………………………………………………

S_{min} = ……………………………………………………………..

(5) Find the slope $S = (S_{max} + S_{min}) / 2$ =………………………………………………

(6) Find the error in the slope $\Delta S = (S_{max} - S_{min}) / 2$

……………..

(7) Find the acceleration due to gravity $g = \frac{a}{sin\theta} = \frac{2S}{sin\theta}$ =

………………………………………………………………………………………….

(8) Find the error in g

Δg =…………………………….…………………………………………………..…

<u>(9) Questions:</u>

(1) Find the velocity of the glider at the bottom of the inclined plane in terms **X, g,** and **sinθ.**

(2) Is g constant at all locations on earth? Why?

(3) Discuss your result for g.

Experiment No. 4
Newton's Second Law

1. Objectives:

Test the validity of Newton's Second Law, by:
(1) Investigating the dependence of acceleration of a body on its mass, when the net force is kept constant.
(2) Investigating the dependence of acceleration of a body on the net force, when the mass is kept constant.

2. Apparatus:

Air track, Glider, air pump, timer with two photogates, spirit level, weights of masses 5g, 10g, 15g, 20g, and 50g hangers.

3. Theory:

Newton's Second Law states that the acceleration of a body is proportional to the net force acting on the body ($\vec{a}\ \alpha\ \vec{F}_{net}$) and inversely proportional to the mass of the body ($a\ \alpha\ \frac{1}{m}$).

Combining these two, we can write:

$$\vec{F}_{net} = m\vec{a}$$

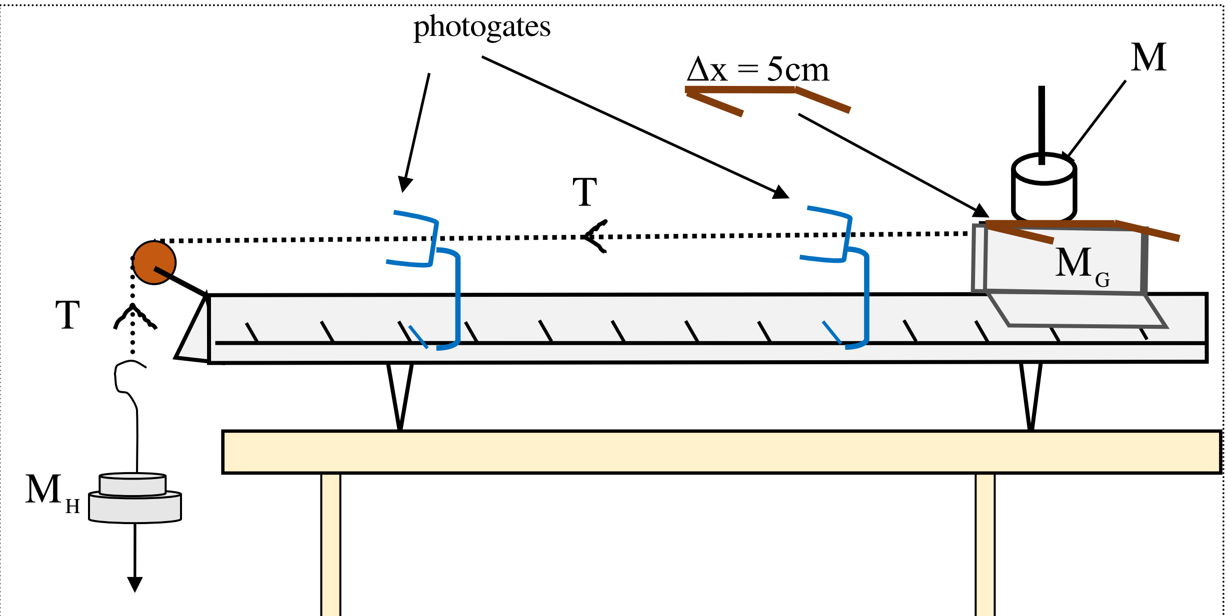


Fig.4.1: Air track for Newton's 2nd Law

Where $\vec{F}_{net}$ is the sum of all of the forces acting on the body. In this experiment, a very low-friction air track will be used to test the validity of Newton's Second Law. A hanging mass will be attached to a glider placed on the air track using 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 systems constant by moving mass from the glider to the hanger. With the air track turned 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 $v_x = \frac{\Delta x}{\Delta t}$. In our case Δx 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:

$$v_2^2 = v_1^2 + 2aS$$

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. Solving for the acceleration yields:

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

Or determine the acceleration knowing the time the glider travels between the two photogate timers:

$$a = \frac{v_2 - v_1}{t}$$

Free body diagrams of the forces acting on the glider and hanging mass are shown in Fig. 4.2. T is the tension in the string; $F_H = M_H g$ is the weight of the hanging mass where g is the acceleration due to gravity. Since the air track is horizontal and the glider does not accelerate in the vertical direction, the normal force and the weight of the glider are balanced, $N = M_G g$. Applying Newton's Second:

$$M_H g - T = M_H a \qquad (1)$$

$$T = (M_H + M_G + M)\, a \qquad (2)$$

Combining the two equations 1 and 2, to get

$$M_H g = (M_H + M_G + M)\, a \qquad (3)$$

This is Newton's Second Law applied to our two-body system

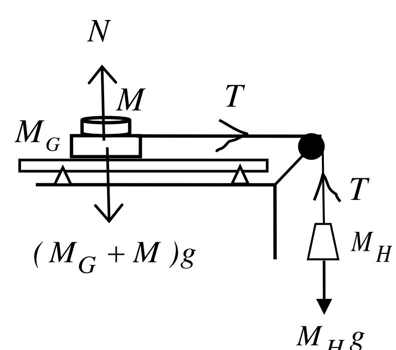


Fig. 4.2

4. Procedure

Part I. changing m keeping force constant.

The load mass to glider m is changed, the hanger mass is kept constant M_H = 10 g, then

$$\frac{1}{a} = \frac{M_H + M_G}{M_H g} + \frac{M}{M_H g}$$

1. Set up the air track as shown in Figure 4.1. 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 (Δx =5cm) of the fin on top of the glider and record it in your spreadsheet. See Figure 4.1 for a definition of various lengths that will be used throughout this experiment.

3. Measure the mass of the glider (M_G) and empty hanger (M_H) and record these masses in your spreadsheet.

4. Using the 5, 10, and/or 20-gram masses, Increase the mass on the glider up to 40 grams. 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 of Table 1.

5. Plot $\frac{1}{a}$ against the added mass M to the glider. From this plot,

(1) Determine the vertical-intercept $b = \dfrac{M_H + M_G}{M_H g}$ and from it the mass of the glider

considering m_H and g to be known.

(2) Determine g by finding the slope $S = \dfrac{1}{M_H g}$

Part II: Dependence of acceleration on force at constant mass

1. Note that the total mass of your system (M_H + M_G + M) should remain constant throughout the experiment and always be equal to the value of the total system mass (M_H +M_G +40). You are just redistributing 40 grams of mass between the glider and the hanger during the experiment.

2. Let the glider accelerate, with all the 40 grams on the glider and the hanger empty. Tabulate. Tabulate your data and calculations in Table (2).

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

Note that: $M_H g = (M_H + M_G + M)\, a$

Plot $F_H = M_H g$ against **a**, find the slope S, it should equal the total mass

$S = (M_H + M_G + M) = M_G + 50$ Find M_G From S.

Exp. No. 4

Newton's second law

Name: ………………………………………………………………………………….…. Grade: ……………………………………………

Student's No.: ………………………………………………………………….. Day and Date: ……………….……………………………

Partners Names: ……………………………………………………………………..………………………………… Sec.: ……………….………

Data:

Part I. changing m keeping force constant. ($M_H = \cdots\cdots\cdots\cdots\cdots M_G = \cdots\cdots\cdots\cdots\cdots$ **)**

M (gram)	t_1 sec	t_2 sec	t_3 sec	v_1 cm/ sec	v_2 cm/sec	a cm/sec^2	1/a

(1) Plot $\frac{1}{a}$ vs. M and determine M_G from the vertical intercept. $b = \frac{M_H + M_G}{M_H g}$

Determine g by finding the slope $S = \frac{1}{M_H g} \Rightarrow g = \frac{1}{M_H g}$

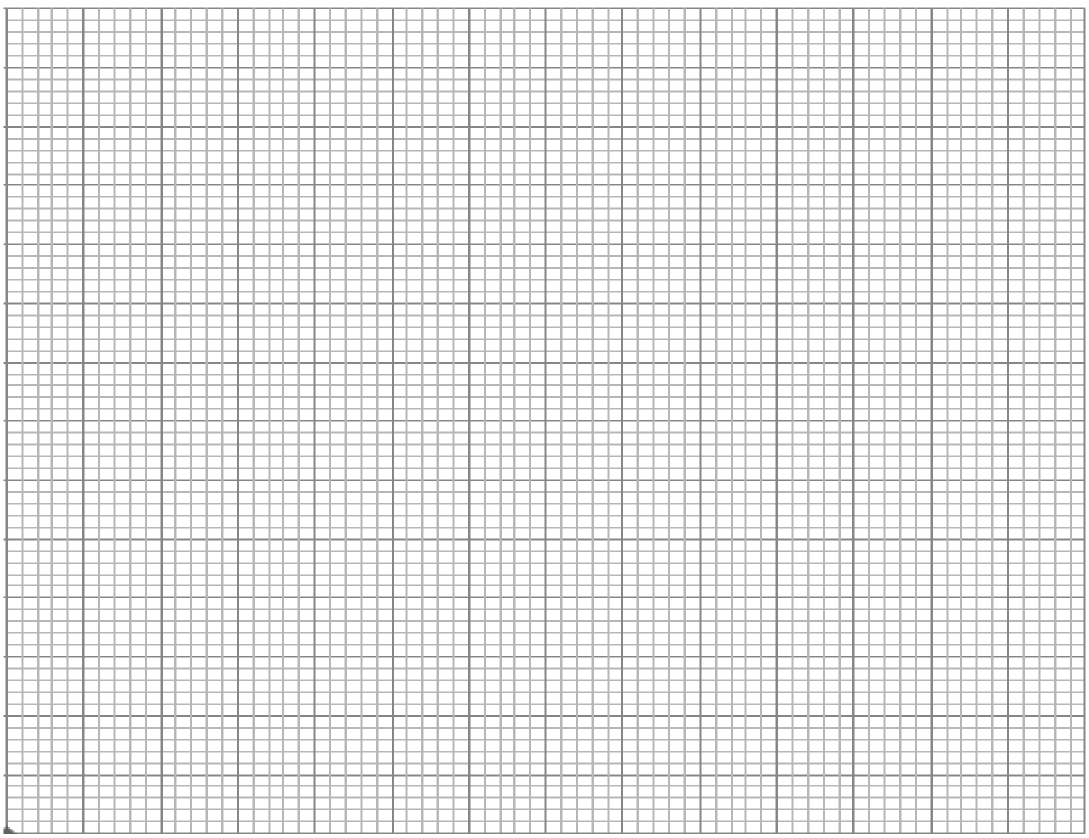
Measured M_G	**From graph M_G**	$\frac{\Delta M_G}{M_G}\%$	**Accepted g**	**From graph g**	$\frac{\Delta g}{g}\%$
(gm)	(gm)		(cm/sec^2)	(cm/sec^2)	
			980		

Part II: Dependence of acceleration on force at constant mass

M (g)	$F_{net} = M_H g$ (dyne)	t_1 sec	t_2 sec	t_3 sec	v_1 cm/	v_2 cm/sec	a cm/sec^2

Plot $F_{net} = M_H g$ **versus a, and determine the slope = total mass**

$S = (M_H + M_G + M) = M_G + 50$ Find M_G From S.



Slope = total mass (gm)	(M_G from slope) (gm)	$\frac{\Delta M_G}{M_G}\%$

Experiment No. 5
Friction

Objective:

To determine the coefficient of Static and Kinetic Friction.

Apparatus:

Horizontal Plane can be inclined at variable angles, frictionless pulleys, Wooden Block, String, Mass holders, 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 attempts to slide across another. The direction of the fractional force on each body is to oppose the motion of the body. 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**^{o} 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 the 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 f_s 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:

$$f_s^{max} = \mu_s N \qquad (1)$$

Where N stands for the normal force between the two surfaces. The meaning of equation (1) is that the static friction force varies in response to the applied force 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 moving with respect to each other. It is called kinetic friction, and it is characterized by a constant μ_k, which is called the coefficient of kinetic friction. The kinetic friction force f_k is given by:

$$f_k = \mu_k N$$

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, some force is sufficient to accelerate an object because once it is moving, the kinetic friction force is less than the applied force.

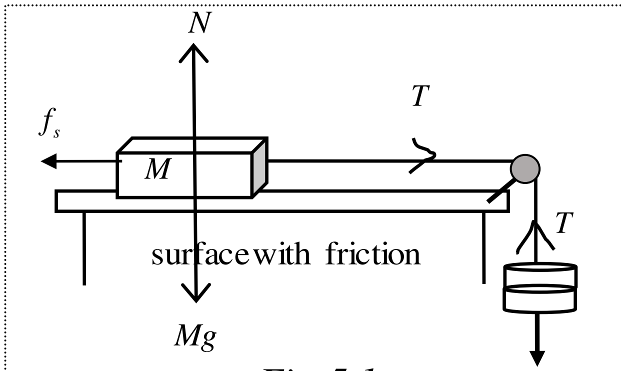


Fig.5.1

The maximum value f_s^{max} is reached when the object is about to move

$$f_s^{max} = \mu_s N,$$

μ_s is the coefficient of static friction, but

$$f_k = \mu_k N\ ,$$

acts when the object is moving relative to the surface, μ_k, the coefficient of kinetic friction.

(1) Horizontal plane:

(a) When M is on the verge of motion (a=0)

$$T{=}m_s g,\quad f_s = T \quad \Rightarrow \mu_s = \frac{f_s}{N} = \frac{m_s g}{Mg},$$

(b) When M is <u>moving **with constant velocity**</u> (a=0)

$$T{=}m_k g,\quad f_k = T \qquad \mu_k = \frac{f_k}{N} = \frac{m_k g}{Mg},$$

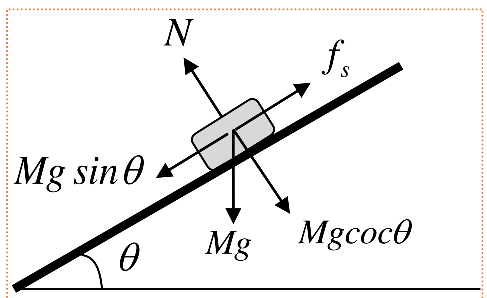


Fig.5.2

(2) Inclined Plane:

Increase θ until the object is just starting to move, then

$$\boxed{\mu_s = \frac{f_s}{N} = \frac{Mg\sin\theta}{Mg\cos\theta} = \tan\theta}$$

If the object is forced to move up the plane by the application of tension in the string attached to load over a pulley then

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

See Fig. 5.3 $(a_x = 0, v = constant) \quad \Rightarrow$

$$T - Mg\sin\theta - f_k = 0, \qquad T = m_k g$$

$$f_k = \mu_k N = \mu_k(Mg\cos\theta)$$

$$f_k = m_k g - Mg\sin\theta$$

$$\mu_k Mg\cos\theta = m_k g - Mg\sin\theta$$

$$\mu_k = \frac{m_k g - Mg\sin\theta}{Mg\cos\theta} = \frac{m_k}{M\cos\theta} - \tan\theta$$

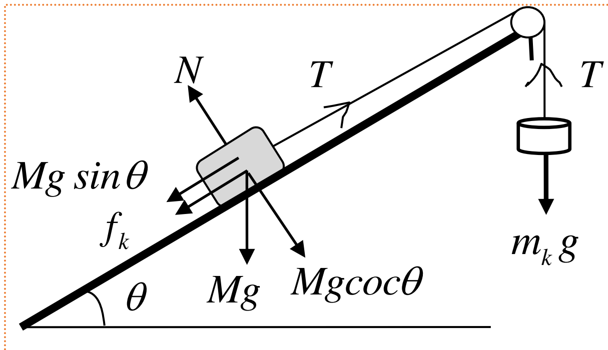


Fig.5.3

Procedure:

I) Horizontal Plane Method:

(1) Set the plane in the horizontal position.

(2) Attach a cord and a weight hanger to the box as shown in **Fig. 5.1**.

(3) Gradually increase the load on the weight **hanger until the box is about to slide.**

(4) Record load mass ***M*** **including the mass of the weight hanger.**

(5) Repeat this **procedure some**times for different masses added to the box say 200, 40**0**, or 50**0** grams subsequently, and find the necessary hanging weight in each case that allows the box just start to move**.**

(6) Repeat the procedure from steps 1 to 5 and find the necessary hanging weight in each case that **pulls the box at constant velocity.** In each calculate μ_k the coefficient of kinetic friction.

(7) Fill your data and results in table (5.1) to find μ_s and μ_k .

II) Incline Plane:

(1) Determine the angle θs for which the block **is about to slide down** (see Fig. 5.2) by increasing the angle of inclination until M is on the verge of motion, then find μ_s.

(2) Arrange the incline as in Fig.5.3, for an **angle less than that θs** increase the **hanging mass** so that the box with and without load moves at a **constant speed**. Determine μ_k from the equation

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

Exp. No. 5

Friction

Name: ………………………………………………..……….. Grade: ……………………

Student's No.: …………………………………………… Day and Date: ……………....……

Partners Names: ……………………………….…………… Sec.: ………..………..………

DATA: Part1: Use the horizontal plane and fill the table below:

Trial	**M (kg)**	**m_s (kg)**	**N=Mg**	$f_s = m_s g$	$\mu_s = \frac{f_s}{N} = \frac{m_s g}{Mg}$	**m_k (kg)**	$f_k = m_k g$	$\mu_k = \frac{f_k}{N} = \frac{m_k g}{Mg}$
Without load								
With load								

(1) What is the value of $\mu_s =$……………………………………….……...…..

(2) What is the value of $\mu_k =$………………..………………………….………..

Part2: Use the inclined plane and fill the table below

Trial	b	H	θ_s	tan θ_s=h/b	$\mu_s = tan\,\theta_s$	$\bar{\mu}_s$
Without load						
With load						

Trial	θ	m_k	cos θ	tan θ	μ_k	$\bar{\mu}_k$
Without load						
With load						

<u>Derive the equation</u> $\mu_k = \frac{m_k}{M\cos\theta} - \tan\theta$ **and use it to fill the table above.**

Experiment No. 6
Uniform Acceleration Motion

1. Objectives:

(1) To study the motion of freely falling bodies.
(2) To evaluate the acceleration due to the gravity.

2. Apparatus:

Free falling set with electronic timer, meter stick, two photogates connected to the timer, and steel balls.

3. Theory:

A body under constant acceleration is uniformly accelerated motion. This is when a constant external force is applied to the body. The acceleration is the rate of change of velocity with time. It is positive when the velocity increases, and negative when the velocity decreases. If the only force acting on an object is gravity (neglecting the air resistance), then the object is said to be in "*free fall*". Free-fall motion is a uniformly accelerated motion that, takes place in a vertical direction say the y-axis. Anytime the object moves vertically, either going upwards or going downwards, is said to be Free-fall.

Since the force of gravity near the surface of the Earth is constant, when we look at a specific location, the free-fall acceleration is also constant. This acceleration is directed downward and its magnitude is denoted by g. The accepted value of g is 9.80 m/s^2, but this value varies from location to location on the whole earth.
When an object is in Free-Fall the acceleration is a constant -g, therefore:

$$a_y = -g = \frac{\Delta v_y}{\Delta t} = \frac{v_{yf} - v_{yi}}{t}$$

But since a = -g is constant, the average velocity during any time interval t can be written as:

$$\bar{v}_y = \frac{v_{yf} + v_{yi}}{2}, \quad \text{and}$$

$\bar{v}_y = \dfrac{\Delta y}{\Delta t}$, for objects falling down a distance y in time t

$$\bar{v}_y = \frac{-y}{t},$$

$$\bar{v}_y = \frac{v_{yf} + v_{yi}}{2} = \frac{v_{yi} + v_{yi} - gt}{2} = v_{yi} - \frac{gt}{2}$$

$$-\frac{y}{t} = v_{yi} - \frac{gt}{2}, \qquad y = -v_{yi}t + \frac{1}{2}gt^2$$

The body will be released at initial velocity zero, then

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

It is clear that, when objects of different masses are allowed to fall freely from rest, the objects will fall at identical distances in identical times. They reach the ground with the same final velocity.

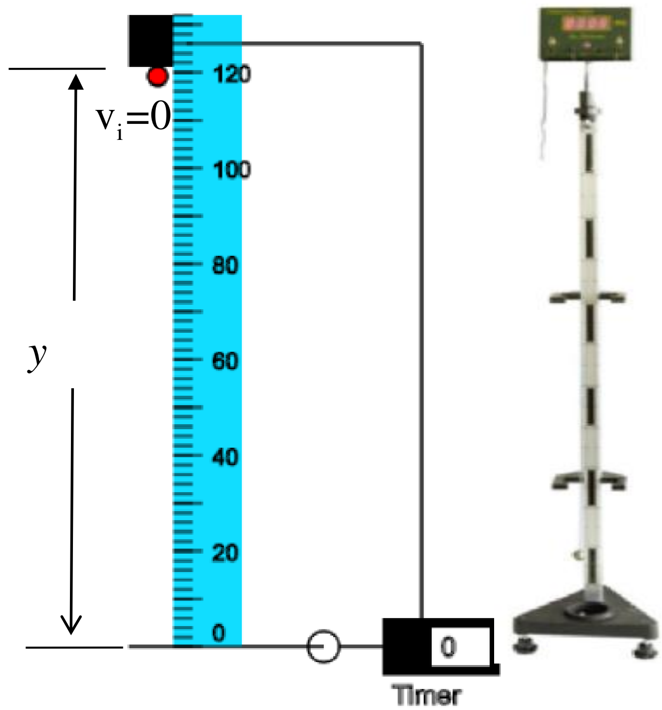
If an object of mass (m) falls freely from rest ($v_{yi} = 0$) then the vertical distance covered in time (t) is given by:

$$y = \frac{1}{2} g t^2$$

The plot of (y) versus (t^2) will give a straight line whose slope S is

$$S = \frac{1}{2} g$$

In this experiment, you will determine the acceleration due to gravity (g) by measuring the free fall distance (y) and the free fall time (t).



4. Procedures:

A. Free Fall time does not depend on distance.

(1) Use a free fall distance of about 0.9 m, make three measurements of the free fall time of the small steel ball, three measurements for the big steel ball, and three others for the big copper ball.
(2) Change the distance and repeat the above measurements.

B. Determination of g from the graph.

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

Exp. No. 6

Uniform Acceleration motion

Name: ………………………………………………………… Grade: ……………………….………

Student's No.: ………………………………………………. Day and Date: ……….…………...……

Partner's Names: ……………………………………………...…... Sec: ……………………….

Density of steel, $\rho_{st} = 7.9$ gm/cm^3, copper $\rho_{Cu} = 8.23$ gm/cm^3

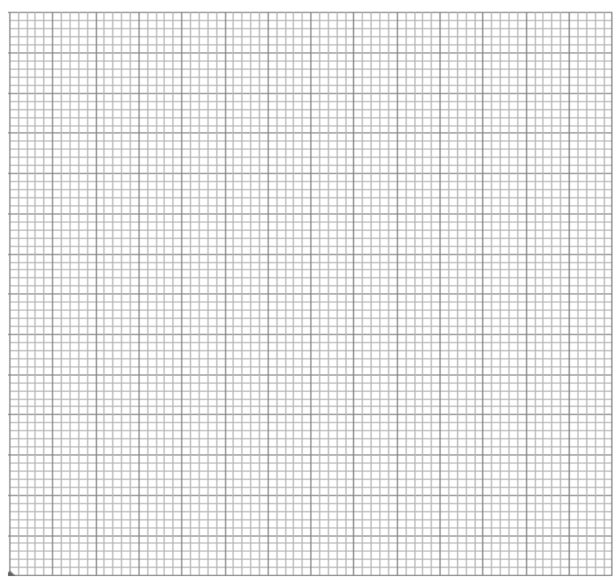
Trial	Mass of the ball	t_1	t_2	t_3	$\overline{t}$

Table 1: To show that free fall time does not depend on mass

Table 2: Fill table 2 and use it to determine the acceleration due to gravity g.

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

(1) From the graph of y versus $\overline{t}^2$



Find the slope S and g

S = ……………………

g = ……………………

(2) Calculate the error in g, Δ**g=2ΔS**

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

Question 2: Derive the equation $y = \frac{1}{2} g t^2$.

Experiment No.7
Atwood Machine

OBJECTIVE:

To study the relation between force, mass, and acceleration using an Atwood Machine and to determine acceleration due to gravity

METHOD:

Consider the Atwood machine shown in Fig. 1. A pulley is mounted on a support a certain distance above the floor. A string with loops on both ends is threaded through the pulley and different masses are hung from both ends. The smaller mass is placed near the floor and the larger mass near the pulley (the pulley can be adjusted to the appropriate height). The masses are then released and the time for them to exchange places is measured.

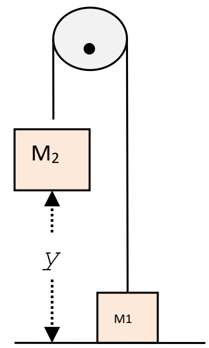


Figure 1

APPARATUS:

Pulley, loads with a stopwatch, string, and meter stick.

METHOD:

Consider the Atwood machine shown in Fig. 1. A pulley is mounted on a support a certain distance above the floor. A string with loops on both ends is threaded through the pulley and different masses are hung from both ends. The smaller mass M1 is placed near the floor and the larger mass M2 near the pulley (the pulley can be adjusted to the appropriate height). The masses are then released and the time for them to exchange places is measured.

THEORY:

Consider the larger mass, M_2. Two forces are acting on it. One is the force of gravity, $W_2 = M_2 g$, pulling it downward. The other force is the tension in the string, T_2, which is pulling it upward. Taking up to be the positive direction, Newton's 2nd Law gives, For (M_2), ($T_2 < M_2 g$)

$$\sum F_y = M_2 g - T_2 = M_2 a_2, \qquad (1)$$

Now consider the smaller mass, M_1. Again two forces are acting on it. One is the force of gravity pulling it downward. The other force is the tension in the string pulling it upward. Thus, Newton's 2nd Law gives ($T_1 > M_1 g$)

$$\sum F_y = T_1 - M_1 g = M_1 a_1, \qquad (2)$$

Because the string is attached to both masses, $a_2 = -a_1 = a$. We now assume that the string's mass is much less than either of the hanging masses and that the pulley does not rotate as the masses move. This allows us to say that $T_1 = T_2 = T$. (In reality, the pulley does rotate and the tensions can't be equal if it rotates. However, we assume that the pulley's motion takes very little energy from the system so we can approximate it as being stationary. Another way to put this approximation is that we are using a "massless" pulley and a "massless" string.) With this assumption, adding the 2 equations to get

$$M_2g - M_1g = M_2a + M_1a \quad \Rightarrow (M_2 - M_1)\cdot g = (M_2 + M_1)\cdot a$$

The net force on the system

$$F_{net} = (M_2 - M_1)g = (M_2 + M_1)a \quad (1)$$

The theoretical acceleration is (a), then is

$$a_{th} = \frac{M_2 - M_1}{M_2 + M_1} g_{th}, \quad g_{th} = 9.8 m/s^2 = 980 cm/s^2 \qquad (3)$$

When M_2 falls with acceleration from rest then, the fall distance y is given by:

$$y = \frac{1}{2} a_{exp} t^2 \ , \quad a_{exp} = \frac{2y}{t^2} \qquad (4)$$

The experimental acceleration a_{exp} is to be determined by measuring the average time of fall for some trials of different masses.
Experimentally, we have to determine the acceleration due to gravity using

$$a_{exp} = \frac{M_2 - M_1}{M_2 + M_1} g,$$

A plot of a_{exp} versus $\frac{M_2 - M_1}{M_2 + M_1}$ gives a straight line with slope g.

<u>Procedure:</u>

(1) Mount a clamp to the edge of the 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. Fasten mass hangers to each and end of the thread.

(3) 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 lightly more than 100 grams on the other hanger. Record this total mass as M_2.

(4) 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.

(5) Use the distance and the average time square to calculate the experimental acceleration (a_{exp})

(6) Change the mass on the hangers each trial and try to make the difference between them small compared to the total mass.

(Fill the tab in the lab report and find g from your slope of **a_{exp}** vs. $(M_2-M_1)/(M_2+M_1)$.

Exp. No. 7

Atwood's Machine

Name: …………………………………...……………..……..……… Grade: ………………………….….

Student's No.: ……………………………………….........Day and Date: …………………………..…

Partner's Names: ………………………………………………………Sec: ……..………….……..…..

(1) Fill the table below

	M_1 (g)	M_2 (g)	$t_1(s)$	$t_2(s)$	$t_3(s)$	$\bar{t}$ (s)	$\bar{t}^2$	Y(m)	a_{th}	F_{net}	a_{exp}	$\frac{M_2 - M_1}{M_2 + M_1}$
Run1												
Run2												
Run3												
Run4												
Run5												
Run6												

(2) Plot $\mathbf{a_{exp}}$ versus $\frac{M_2 - M_1}{M_2 + M_1}$ find the slope.

Slope =S= ……………………………...

g = …………..………………………

Δg = …………………………………

Questions:

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

(2) What is the net force in an Atwood machine if M_1=1 kg and M_2=2 kg?

Experiment No.8
Energy Conservation

Objective:

To experimentally verify the conservation of energy law.

Apparatus:

Flex-track, balls (steel spheres), ruler, electrical balance, sheets of legal paper to be used as target paper, and sheets of carbon paper.

Theory:

In the absence of non-conservative forces, such as friction or air drag, the total mechanical energy, which is the **kinetic energy K** and **potential energy U,** remains a constant during the motion and we say that mechanical energy is conserved. The total energy at two different locations is unchanged in the absence of other external forces.

In this experiment, you will demonstrate the **conservation of the total mechanical energy** of a system using Flex-track. A sphere is released from rest at point A and rolls without slipping down the flex track and reaches the point B with velocity V. Point A is at height **h** relative to the point **B** at the bottom of the track which is assumed to be a reference point for the potential gravitational energy taking $\mathbf{U_g = 0}$.

At the top (point A) and the bottom (point B) the total mechanical must be conserved. The energy at A is potential and at B is Kinetic. But since the sphere is rolling its kinetic energy at B is translational kinetic energy plus rotational kinetic energy, so we can write:

$$E_A = mgh\,,$$

$$E_B = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

Where I is the moment of inertia for a sphere of radius R and equals

$I = \frac{2}{5}MR^2$ **, and the angular speed** (relative to the center of the sphere) $\omega = \frac{v}{R}$, with this

$$E_B = \frac{1}{2}mv^2 + \frac{1}{2}\frac{2}{5}mR^2\left(\frac{v}{R}\right)^2 = \frac{1}{2}mv^2 + \frac{2}{10}mv^2 = \frac{7}{10}mv^2$$

From the conservation of energy:

$$mgh = \frac{7}{10}mv^2$$

From the above equation, the calculated value of the velocity of the sphere at B is

$$v_{th} = \sqrt{\frac{10}{7}gh}$$

In the experiment, the spheres leave point B with horizontal velocity v and fall on the ground with horizontal distance x, measured from the vertical line at the point below B on the floor. Since

$$y = \frac{1}{2} g t^2 \Rightarrow t = \sqrt{\frac{2y}{g}}$$

And from

$$x = vt \quad \Rightarrow v_{exp} = \frac{x}{t}$$

The value of the velocity of the sphere at point B is determined by measuring x.

If speed and h are in cm and mass in grams the unit of energy is Erg

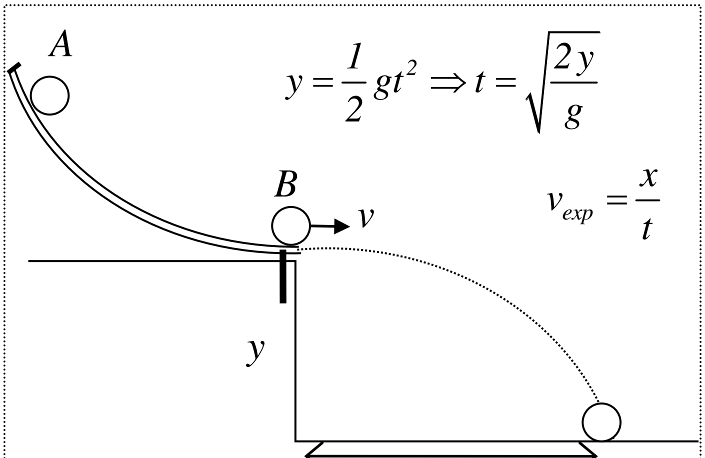


Fig. 8.1

1 Erg = 1gram. cm/s^2. cm
= 1 dyne. cm
= 10^{-5}N. 10^{-2}m= 10^{-7} N.m = **10^{-7} Joule**

Procedure:

(1) Measure the mass of the sphere and record it.

(2) Lay the carbon paper on the floor, carbon side up, and put a sheet of 18" by 24" paper on top, with the plumb bob hanging over the middle of the shorter side. ("Plumb" means vertical).

(3) Mark the point under the plumb bob.

(4) Adjust the screw at the bottom end of the track so that the sphere falling from A will freely pass the point B to the ground.

(5) Release the sphere from point A at least 10 times. This will locate the distance X to determine the velocity sphere at B.

(6) Measure the distance x from the plumb bob to the cluster of impact points.

(7) Repeat step 6 for the same pair of balls but for a different h.

(8) Tabulate your results as in Table 8.1.

(9) Repeat steps 1-6 for a different height h.

(10) Repeat the steps for different spheres of mass m_2

(11) Tabulate your results in Table 8.1.

Exp. No. 8

Energy Conservation

Name: ……………………………………………………….………….. Grade: …...............................

Student's No.: ……………………………………....... Day and Date: …………………………

Partners Names: …………….…………………………….……..……… Sec.: …………………

Table 8.1

Mass1	h(cm)	Y(cm)	t(sec)	x(cm)	V_{th}	V_{exp}

Table 8.2

$E_A = mgh$	$E_B = \frac{7}{10} m(v_{th})^2$	$E_B = \frac{7}{10} m(v_{exp})^2$

Q1. Compare the values calculated in columns 1 with 2 and 3 in table 8.2.

Q2. Is the energy of the rolling sphere conserved between A and B?

Q3. Calculate **the time** of fall from y= 40 cm, and find the energy E for **x=28 cm** in Ergs (Er) and Joules (J). What is the potential energy at point A in Er and J for **h=7 cm**? What is E at B for this h? (take **m=10 gram**)

Experiment No. 9
Conservation of Linear Momentum

Objective:

To verify experimentally that momentum is conserved during one-dimensional and two-dimensional collisions.

Apparatus:

Flex-track, balls (steel spheres), ruler, electrical balance, sheets of legal paper to be used as target paper and sheets of carbon paper.

Theory:

The total linear momentum of an isolated system is conserved or is constant. When two particles with masses m_1 and m_2 moving initially at velocities $\vec{v}_{1i}$ and $\vec{v}_{2i}$ collide, their total momentum is conserved. From Newton's third law at the instant of collision, (action force = – reaction force),

$$\vec{F}_{12} = -\vec{F}_{21} \qquad \Rightarrow m_1\vec{a}_1 + m_2\vec{a}_2 = 0,$$

Where, $\vec{a}_1$, and $\vec{a}_2$ are the accelerations at the instant of contact.

$$\frac{d}{dt}(m_1\vec{v}_1 + m_2\vec{v}_2) = 0 \quad \Rightarrow m_1\vec{v}_1 + m_2\vec{v}_2 = constant \ \ quantity$$

$$\vec{p}_{total}(initial) = \vec{p}_{total}(final)$$

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

Where $\vec{v}_{1f}$ and $\vec{v}_{2f}$ are the velocities of the two particle after collision. Which means that the momentum in a specific direction before a collision must be equal to the momentum in that same direction after the collision.

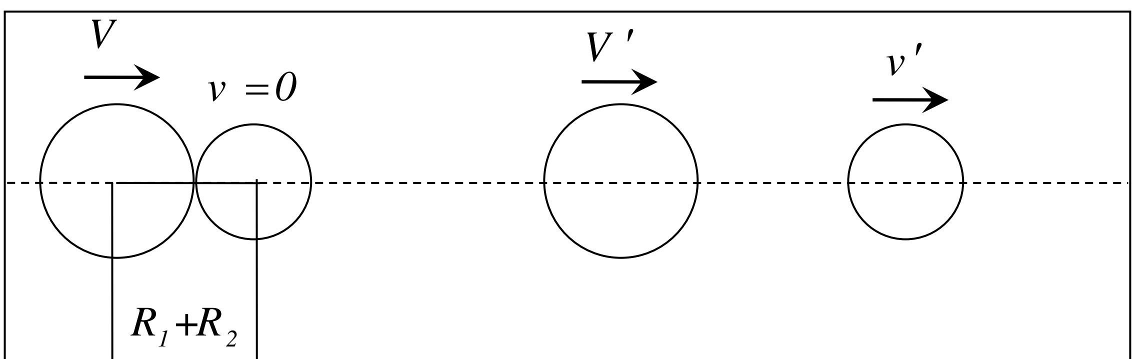
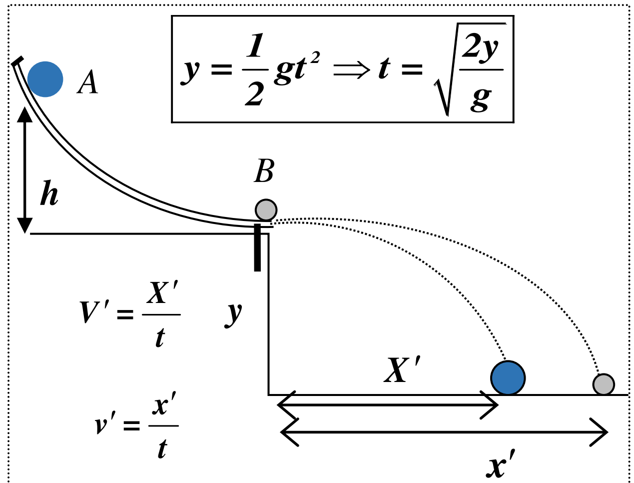


Fig. 8.1: 1D head on collision – motion along the same line

Collision in one dimension:

The colliding particle undergoes collision and move before and after collision in the same direction. (Fg.8.1)
In this experiment, a larger mass **M falls from rest at point. A** and rolls down the flex track and reach the point B with **velocity V**, where it collides **a head –on –collision** with the small sphere **m** at **rest**, after collision the two spheres move along the same line and fall down on ground with **horizontal distances X and x** for **M and m, respectively**, measured from the vertical line at the point **below B** on the floor.



The initial momentum before collision is MV and the final momentum of the two balls after collision is $MV' + mv'$**,** since the collision in one direction:

$$MV = MV' + mv'$$

To determine the velocity **V** of the incident sphere **M** at **B before collision**, **M** is released from A down the track to B **without the target ball m** on the screw, **M** will fall down to floor at a horizontal distance X. Since V=X/t:

$$M\frac{X}{t} = M\frac{X'}{t} + m\frac{x'}{t}$$

$$\Rightarrow MX = MX' + mx'$$

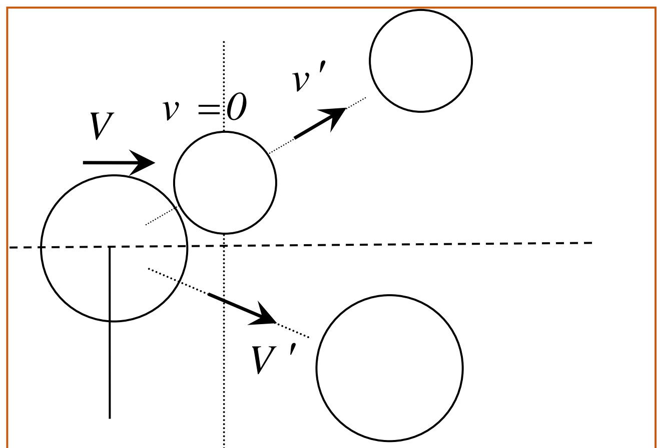
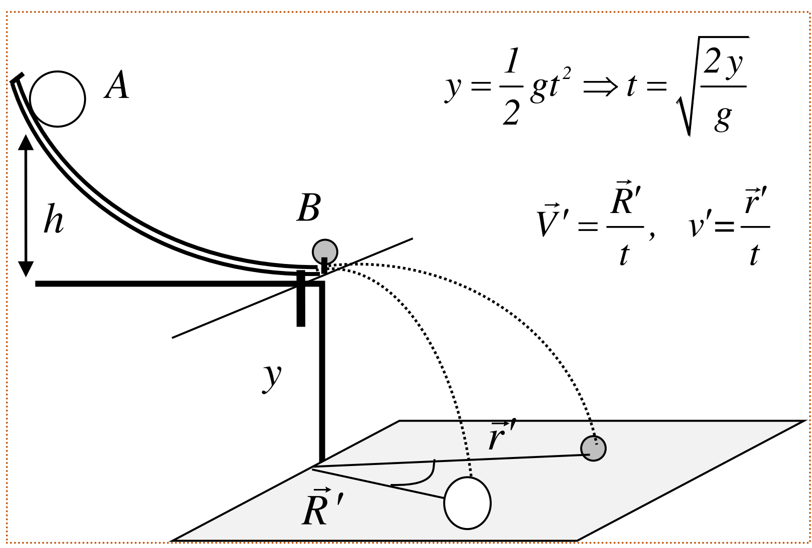


Fig. 8.3: 2D collision – Collision at glancing angle

Collision in two dimension:

When the sphere M collide with the smaller sphere at rest at **glancing angle**, after this glancing collision the two spheres move in two dimension, the hit the floor at points whose position vectors relative the point below B makes an angle **θ** as shown in **Fig. 8.3**



In **fig.8.4** the position vectors of the location where the spheres land are denoted $\vec{R}'$ for the sphere of mass M and $\vec{r}'$ for the sphere of mass m.

Initial momentum of the two spheres before collision is $\vec{p}_i = M\vec{V} = M\,\dfrac{\vec{R}}{t}$

And after Collision:

$$\vec{p}_f = M\vec{V}' + m\vec{v}', \qquad \text{Since} \quad \vec{p}_i = \vec{p}_f$$

$$M\vec{V}' + m\vec{v}' = M\,\frac{\vec{R}'}{t} + m\frac{\vec{r}'}{t}$$

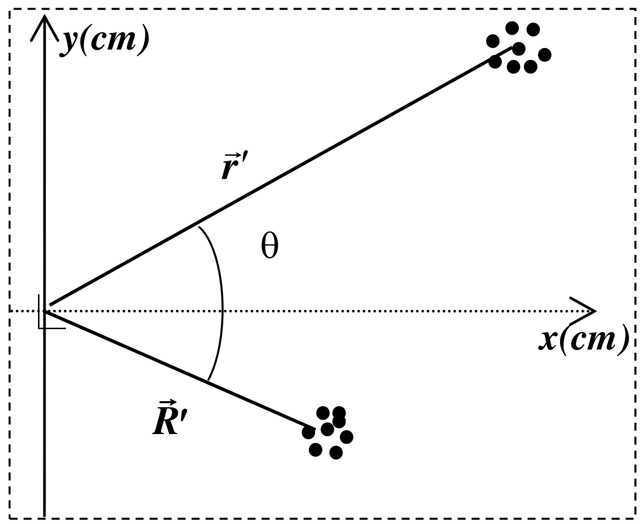
Momentum conservation ensures that

$$M\vec{V} = M\vec{V}' + m\vec{v}' \quad \text{and} \quad M\,\frac{\vec{R}}{t} = M\,\frac{\vec{R}'}{t} + m\frac{\vec{r}'}{t} \qquad \Rightarrow M\vec{R} = M\vec{R}' + m\vec{r}'$$

From which it follows:

$$P_i^2 = (MR)^2 \;\mathbf{=}\; P_f^2 = (MR')^2 + (mr)^2 + 2(MR)(mr)\cos\theta$$

Procedure:



I. Collision in 1-Dimension

(1) Measure the mass of both ball bearings.

(2) Lay the carbon paper on the floor, carbon side up, and put a sheet of 18” by 24” paper on top, with the **plumb bob hanging over the middle of the shorter side**. (“Plumb” means vertical).

(3) Mark the point under the **plumb bob**.

(4) adjust the screw at the bottom end of the track so that **its top is at the same height** as the **bottom of the groove in the ramp**. This way, the incident ball will knock the target ball cleanly off the screw.

(5) Without the target ball in place, **release the other ball at least a dozen times**. This will locate the distance X **to determine the velocity of the incident sphere M at B before collision**.

(6) Sit the **target ball in the dimple of the screw** in such way **that M will hit m at B, and falls at the two points along same line on floor after collision**, so that that the collision **is head on collision.**

(7) Try this one-dimensional collision a dozen of times.

(8) Turn the paper over to see the dots better.

(9) Measure the distances from the plumb bob to each cluster of impact points, these are X, X’, and x’

(10) Tabulate your results in table 8.1.

II. Collision in 2 Dimension:

(1) Repeat the steps **1-5** as in **part I** for **collision in 1-Dimension**.

(2) Turn the arm to which the screw is attached **about 50° or 60° to the side**, such that the ball will **go fast enough to miss hitting the arm as it falls**.

(3) In a trial collision, check that both balls land **at least 10 cm from the plumb bob**. Otherwise, **readjust the angle** the arms make.

(4) Put the target **ball m** on the screw and allow the **ball M** to fall to the target making **a glancing collision**.

(5) Do at least another 10 trials.

(6) Turn the paper over to **see the dots better**.

(7) Measure **the distance from the plumb bob** to each cluster of impact points on the paper (a layout for **the collision in two dimensions** is shown in Fig. 8.5

(8) Repeat **step 6** for the same pair of balls but for a different h.

Tabulate your results as in table (2).

---------------------- **You can do this part only for 2D collision**

(9) Repeat steps **1-8** choosing $m_1=m_2$, fill table (3) and from the dots on the paper obtained measure the distances X, X', x'.

Exp. No. 9

Conservation of Linear Momentum

Name: ………………………………………………. Grade: ……………………..……………

Student's No.: …………………………………………Day and Date: ……………………………

Partners Names: ………………………………………………………Sec: ………………….

Part 1: Collision in 1D. (Table 1)

Mass1	Mass2	h(cm)	y(cm)	X (cm)	X′ (cm)	x' (cm)	V(cm/s)	V′(cm/s)	v'(cm/s)

MV (gm.cm/sec)	mv' (gm.cm/sec)	MV' (gm.cm/sec)	MV'+ mv' (gm.cm/sec)

Q1. Compare the values calculated in columns 1 and 4. (They must be equal)

Part II: Collision in 2D. (Table 2)

Mass1	Mass2	h(cm)	$\vec{R}$ (cm)	$\vec{R}'$ (cm)	$\vec{r}'$ (cm)	θ_1	θ_2	$\theta=\theta_2-\theta_1$

h(cm)	$P_i^2=(MR)^2$	$P_f^2=(MR')^2+(mr')^2+2(MR')(mr')\cos\theta$

Table (3)

Mass1=Mass2	h(cm)	X (cm)	X' (cm)	x' (cm)	θ	$\vec{X}+\vec{x}$
						$\theta=\theta_2-\theta_1$

Q2. Compare the values calculated in columns 2 and 3. (They must be equal)

Q3. Since $\vec{p}_i=\vec{p}_f$ and $\vec{p}_i$ is along the x-direction, check whether $p_{fy}=0$.

Q4. From table 3, measure vectors X, X', and x', find the sum <u>from the graph</u>, does this sum equals vector X

Experiment No. 10
Pendulum

Objectives:

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

Theory:

An oscillating system that undergoes uniform periodic rectilinear motions, is called "Simple Harmonic Motion, (SHM)". In general, any motion that repeats itself at regular intervals is SHM, when the object is subjected to a restoring force proportional to the displacement and acts in the opposite direction. Examples, are an oscillating block hanging vertically from a spring, and a simple pendulum.

A body that executes simple harmonic motion in the y-direction, the location in the y-axis at any given time (t) from the start is given according to the equation

$$y = A\,sin(\,\omega t\,)$$

Where *y* is the displacement of the body from its equilibrium position at $y = 0$, *t* is the lapse of time and is measured such that at $t = 0$, $y = 0$; *A*, the amplitude of the motion, is the maximum displacement of the body from its equilibrium position, and **is the angular velocity** of the motion. The velocity at any time

$$v = \frac{dy}{dt} = A\omega\;cos(\,\omega t\,)$$

$$\Rightarrow a = \frac{d^2y}{dt^2} = -\omega^2 A\;sin(\,\omega t\,) = -\omega^2 y \qquad \Rightarrow \quad \omega^2 = \frac{-a}{y}$$

The angular velocity $\omega = 2\pi f$ is related to the period of the oscillation by the equation:

$$\omega = \frac{2\pi}{T}$$

The frequency f is in the number of vibrations per unit time. The period T of the vibration (or oscillation) is the reciprocal of frequency.

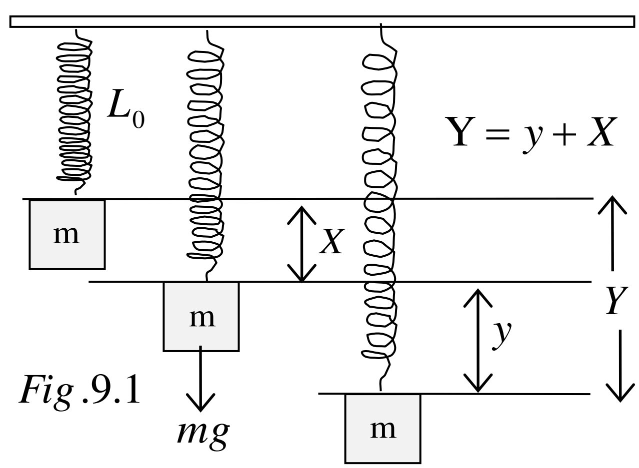


Fig .9.1

In this experiment, you examine two types of oscillatory motion:

(I) spring system: (fig. 9.1) mass attached to spring displaced a distance (-y) from the equilibrium point (y=0), for small displacements the restoring force in the spring is given by Hook's law (F =

- ky) where k is the spring constant. Using Newton's second law and Hook's law for the displacement Y= y+X:

$$ma = -k(\ y + X\ )\ + mg$$

But since

$$-kX = mg \qquad\qquad \Rightarrow ma = -ky$$

Where **X** is the elongation made when the mass **m** attached to the spring and held stationary **(no oscillations).**

Note: When the spring stretches a distance X, and the attached mass is stationary, you can find k from m and the elongation X from equilibrium position (x=0), the spring is with original length L_0.

$$k = \frac{mg}{X}$$

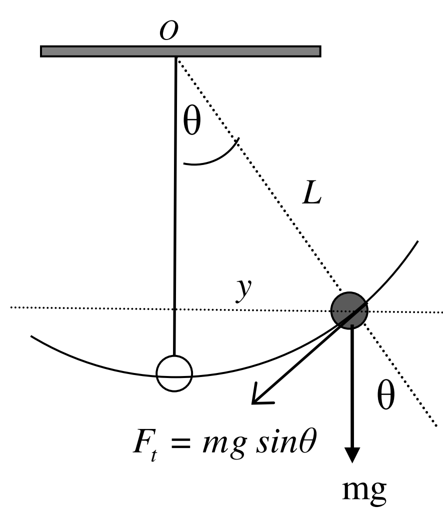
When the mass sets into oscillation, then

$$ma = -ky$$

Therefore: $\omega^2 = \frac{-a}{y} = \frac{k}{m}$

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad \text{and} \qquad T^2 = 4\pi^2\frac{m}{k}$$

(II) Simple Pendulum: the second example you examined for SHM is the simple pendulum, which consists of a mass (m) called the bob, attached to the string of length L. If the bob is moved from the rest at the equilibrium position at the bottom through a small angle of displacement θ as shown in Fig.9.2, the bob will experience a restoring force due to the component of gravity tangent to the path, which acts to bring the bob back to its equilibrium position at the bottom.



When m is displaced for small angles θ, applying Newton's law for the motion tangent to the path of motion:

$$F_t = ma = -mg\ sin\,\theta, \qquad sin\,\theta = \frac{y}{L}$$

$$a = -m\ sin\,\theta = -m\,\frac{y}{L}, \qquad \omega^2 = \frac{a}{y} = -\frac{g}{L}$$

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad \text{and} \qquad T^2 = 4\pi^2\frac{L}{g}$$

Procedure:

(I) mass on a spring:

(1) Suspend the spring vertically from a rigid support.

(2) Use the slotted weights to elongate the **spring from y=0**, and record the displacements b from the equilibrium position when the block becomes **stationary**.

(3) Tabulate your data in Table 9.1

(4) Plot **F_g= mg** versus **X** and from the graph **find k** of the spring.

(5) **Attach a mass to the spring** and **pull it downward a distance (A) from the equilibrium** position.

(6) Find **the period of a vertical oscillation**, use the stopwatch to determine the time needed for 10 oscillations, **do this 2 times, and find the average period T**.

(7) Tabulate your results in Table 9.2.

(8) **Plot T^2 versus m. and find K from the graph**.

(II) Simple Pendulum:

(1) Displace the bob **to one side for a small angle** of displacement.

(2) Release the bob **letting it oscillate**.

(3) Determine the time **needed for 10 oscillations**, **do this step 2 times** and take the average.

(4) Change L and find the average period T each time.

(4) Tabulate your results in Table 9.3.

(5) **Plot T^2 vs L and from the slope determine g**.

Exp. No. 10

The Pendulum

Name: ……………………………………………………….………..……….Grade: ……….…………………

Student's No.: ……………………………………………...… Day and Date: ………………………

Partners Names: ………………………………………………….................... Sec: ………………

<u>Part 1</u>: Determine the spring constant.

Trial	Total mass	Spring elongation	Force of Gravity(dyne)	Spring constant (dyne/cm)
	M (gm)	X (cm)	F= mg (dyne)	K = mg/X (dyne/cm)
1				
2				
3				
4				
5				

<u>Find the value of k:</u>

(1) $k_{avg} = (k_1+k_2+k_3+k_4+k_5)/5$ =
…………………………

(2) Plot <u>mg vs. x</u>.

Determine k from the slope = S = k =
……………………

<u>Part 2</u>: Spring Harmonic Motion.

m(g)	t_1 (for 10 Oscillations)	t_2 (for 10 Oscillations)	Avg. Period T = $(t_1+t_2)/20$	T^2

Plot T^2 versus **m** and determine **k from slope S** (from the table below)

Slope = $S = 4\pi^2/k$ → $k = 4\pi^2/S$ =

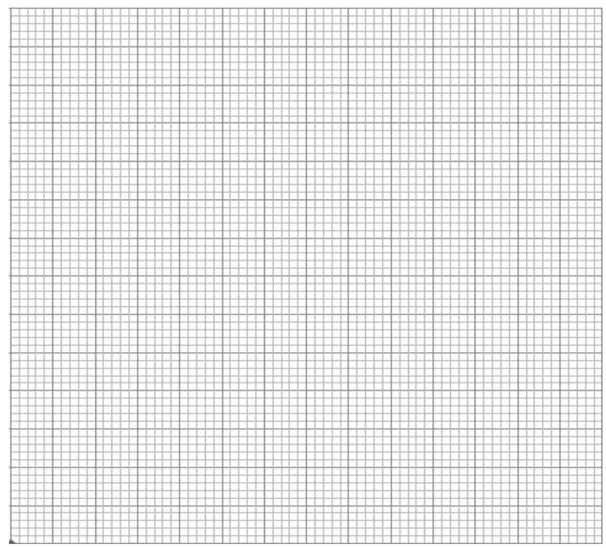
<u>Part 3</u>: Pendulum.

L(length) (cm)	t_1(for 10 Oscillations)	t_2 (for 10 Oscillations)	$T = (t_1+t_2)/20$	T^2

Plot $\mathbf{T^2}$ versus L and determine **g** from slope **S**

Slope = S = $\mathbf{4\,\pi^2/g}$

$\mathbf{g = 4\,\pi^2/S =}$



<u>Questions:</u>

1- Does the period of the simple pendulum, in general, depend on the amplitude?

2-What is the relation between k's and k'eq for parallel and series combinations?

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

Experiment No.11

The Viscosity.

Objective:

1- To show where a small sphere falls with constant terminal velocity inside a viscous fluid

2- To determine the viscosity coefficient η of a fluid

Theory:

The resistance to the fluid flow due to the internal friction between adjacent fluid layers is called **viscosity**.

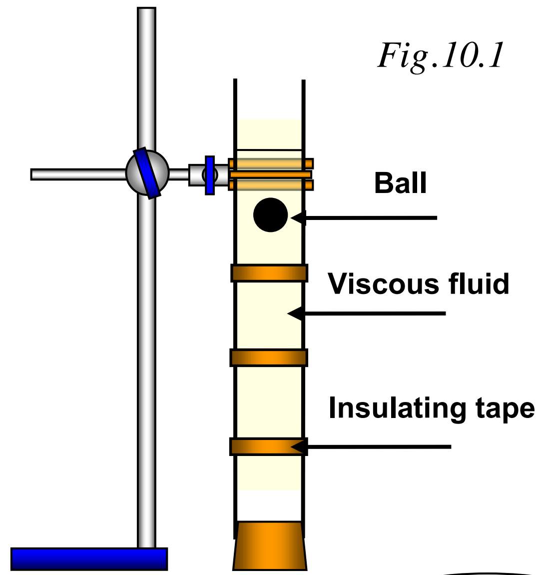


Fig.10.1

When a solid sphere is moving in a liquid, a viscous drag force $\mathbf{F_D}$ will be exerted on the sphere. According to Stokes' law, the drag force is proportional to the viscosity of the fluid, the **radius r =d/2** of the sphere, and the velocity (or speed) of the

$$F_D = 6\pi\eta\, rv = 3\pi\eta\, dv$$

Where, η is the coefficient of viscosity fluid. A steel ball is dropped into a fluid sample so that the gravitational force on the ball, $\mathbf{F_G = mg}$, is larger than the buoyant force $\mathbf{F_B}$. The net driving force *F* on the ball is:

$$mg - F_B = \frac{1}{6}\pi d^3(\rho - \rho_0)$$

If a sphere of diameter **d** and density **ρ** is allowed to fall from rest through a liquid of density ρ_o, it will accelerate by the gravitational force $\mathbf{F_G}$ opposed by viscous force $\mathbf{F_D}$, and the buoyant force, or the upthrust force of the fluid $\mathbf{F_B}$, until it reaches **<u>a constant terminal velocity v_t,</u>** at this point $\mathbf{F_G}$ is balanced by the $\mathbf{F_D}$ and $\mathbf{F_B}$:

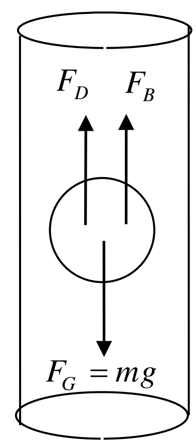


Fig.10.2

$$F_B + F_D = F_G$$

Gravitational force: $F_G = mg = \frac{1}{6}\pi d^3 \rho g$, ρ the density of the ball

Buoyant (upthrust) force: $F_B = \frac{1}{6}\pi d^3 \rho_0$ ρ_0 is the density of the liquid

The viscous force: $F_D = 6\pi\eta\, rv = 3\pi\eta\, dv$ (R>>>r)

The balance of forces is illustrated in Figure 10.2. Equating the balanced forces yields:

$$F_G = F_B + F_D$$

$$F_D = \frac{1}{6}\pi d^3(\rho - \rho_0)g$$

$$3\pi\eta d v_t = \frac{1}{6}\pi d^3(\rho - \rho_0)g$$

$$\boxed{\eta = \frac{g}{18}(\rho - \rho_0)\frac{d^2}{v_t}}$$ Plot d^2 vs. v_t and determine the slope.

The coefficient η is determined by changing the sphere, i.e. the diameter d, and hence the terminal velocity and to plot the d^2 vs. v_t .

Procedure:

(A) Measure the terminal velocity:

1- Select some balls bearing the same diameter.
2- Drop one ball and use the stopwatch to find the time it takes the ball to traverse the required distance.
3- Change the distance and repeat step 2 for a different distance than the one used in step2
4- Tabulate your data in the table.

(B) Determine the viscosity coefficient of the liquid.

1- Choose a fixed distance to use each time.
2- Select 6 spheres of different diameters and measure their diameters using a micrometer.
3- Drop the sphere in liquid and use the stopwatch to find the time
4- Record your data in the table.

Exp. No.11
The Viscosity

Name: ……………………………………….……................….Grade: …………….…………………

Student's No.: ………………………………….............… Day and Date: ………………………

Partners Names: …………………………................…………….................... Sec: ………………

Part 1: to show that a small sphere falls with a constant terminal velocity.
Construct a velocity-time graph and a velocity-distance graph. These will show the ball bearing accelerating until it reaches terminal velocity.

h(cm)	t_1 (sec)	t_2 (sec)	t_3 (sec)	$\bar{t}$ (sec)	$v=h/\bar{t}$ cm/sec

Plot h vs $\bar{t}$ and determine v_t

Part 2: Determination of the coefficient of viscosity:
Repeating the experiment with ball bearings of different mass and diameter will show that the terminal velocities of different bodies are different.

Sphere density = 7.8 gm/cm^3
Liquid density = 1.12 gm/cm^3 h =50 cm

d(cm)	d^2	t_1 (s)	t_2 (s)	t_3 (s)	$\bar{t}$ (s)	V	η

Plot a graph of d^2 vs. v_t. From the graph,

Determine the coefficient of viscosity.

The slope $= S =$

The coefficient of viscosity η =

What is the unit of η: