PHY-1040: GENERAL PHYSICS I LAB

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TABLE OF CONTENTS

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1: Vector Addition of Forces Lab

Learning Objectives

To use the force table to experimentally determine the force that balances two or more forces. This result is checked by analytically adding two or more forces using their horizontal and vertical vector components, and then by graphically adding the force vectors on the force table.

Theory

If several forces are acting on a point, their resultant $\vec{R}$ is given as

$\vec{R} = \vec{A} + \vec{B} + \vec{C}$

$R_x = A_x + B_x + C_x$

$R_y = A_y + B_y + C_y$

R = $R = \sqrt{R_x^2 + R_y^2}$

$\theta_R = \tan^{-1}\frac{R_y}{R_x}$

Then if the equilibrant $\vec{E}$ is a force that brings the system to equilibrium

$\vec{E} + \vec{R} = 0$, this means

$\vec{E} = -\vec{R}$ (E = R, $\theta_E = \theta_R + 180°$)

This means $E_x = -R_x$ and $E_y = -R_y$

Notes for today's lab

(1) Read the details, discuss with your group, and follow the instructions systematically. You have done several of these questions in class so now work by yourselves. If you want more details, look up your textbook or online.

(2) Every time to determine a resultant vector, assess whether it's magnitude and direction makes sense before you proceed.

(3) When working with the force table, do not hang any masses until after you have completed the calculations for the Resultant and Equilibrant.

Method

You will hang some mass on the pulley hangers that are attached by a thread. This means the weight of that mass is a force vertically down. However, the string is attached to the central ring of the force table, and this means a tension equal to the weight of the mass is the force acting on the central ring. This means you can set up one or more forces acting on the central ring, calculate their resultant force (resultant, $\vec{R}$). Then you can determine what force (Equilibrant, $\vec{E}$) would balance these forces to bring the system to equilibrium.

Apparatus

Force table, 4 pulley clamps, 3 mass hangers, 1 mass set, string (or spool of thread)

Force table, an introduction

A force table is a simple set up that can be used to observe vector addition and equilibrium. You can attach a (one or more) pulley at the edge of the table, and hang a mass on a string that goes through this pulley. Hanging mass means a weight is acting downward and the tension on the hanging string is acting upward. However, on the top of the table, the string is attached to a central ring. This string applies a horizontal tension to the ring. The central ring is our object of interest and we will observe the effect of various forces on this ring. You can change the magnitude of the force by changing the hanging mass.

The table surface has a protractor so you can set up vectors in specific directions.

You can find more information online on how a force table works.

If a mass “m” is hanging over the pulley, the mass has a force downward (= the weight of the mass, mg). And the tension on the string is upward. The magnitude of the tension = mg)

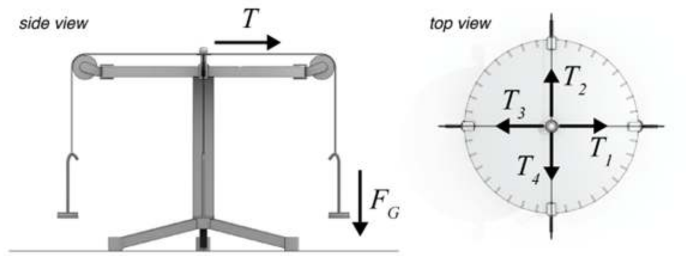


Figure 1.1: Side and top view of the force table (image credit: CCNY CUNY)

Set up the force table such that 0 of the table protractor is on your right (just like x-axis on a Cartesian coordinate system. This means 0°, 90°, 180°, and 270° should be along +x, +y, -x, -y of your coordinate system.

a b c

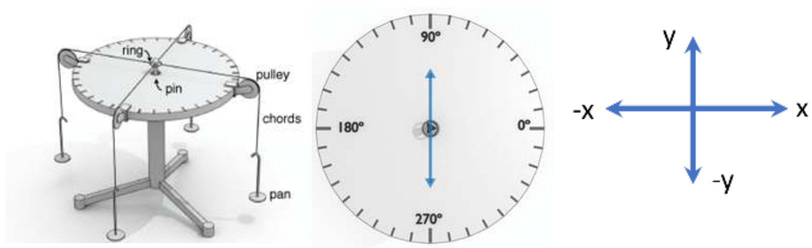


Figure 1.1: a: 3D view of force table with four equal weights, b: Top view of the protractor, c: Vector diagram of the forces

Resultant vs. Equilibrant

The Resultant force is the sum of the individual forces acting on the ring. It means, you can replace all the vectors by the Resultant to get the same effect. The equilibrant is the force that brings the system to equilibrium.

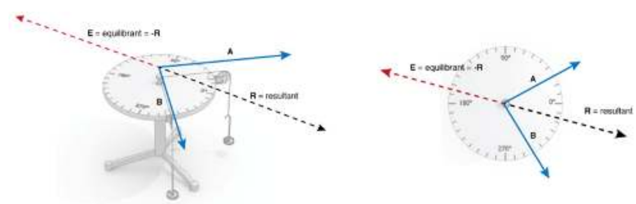


Figure 1.1: Left: 3D view of the force table with two weights hanging at 90° from each other. Right: Top view showing the vector forces and the resultant and the equilibrant (image credit: CCNY CUNY)

Precautions:

(1) Ensure that the central pin on the force table is always attached in place before and while you hang any mass unless otherwise specified. Otherwise the mass can suddenly drop and hurt someone (and also mess your experiment).

(2) Measure/note the mass of each hanger before you use it.

(3) The force needed to balance the force table is not the resultant force but the equilibrant force, which is negative of the resultant.

Part I: Experimental Procedure I, Use of One Force

Step 1: Calculation only. Do not hang any mass yet; you will do that in Step 2 after you finish your data table below.

You will hang a mass (an example: 100 g) on a hanger at 0°. Fill out the table below using these values.

Force	Mass m [g]	Mass m [kg]	Magnitude mg [N]	Angle θ [°]	x-component [N]	y-component [N]

Force	Mass m [g]	Mass m [kg]	Magnitude mg [N]	Angle θ [°]	x-component [N]	y-component [N]
$\vec{A}$						
Resultant						

Then we can write the resultant and the equilibrant below

Force	Magnitude	Angle
Resultant		
Equilibrant		
Mass that you need to hang for this Equilibrant: _______________ g		

Step 2: now hang the mass for force $\vec{A}$. You will notice that the central ring seems to be pulled in the direction of the Resultant force. What should you do to bring it in equilibrium? Write your answer below (one brief sentence):

Then apply the equilibrant force as you determined in your data table above.

<u>To check if the system is actually in equilibrium</u>, remove the central pin (at the center of the ring). If your system is actually in equilibrium, the ring will stay in place otherwise the masses will fall off in the direction on any net force.

Explain your observations.

Part II: Experimental Procedure II, Use of Two Forces

Step 1: Calculation only. Do not hang any mass yet; you will do that in Step 2 after you finish your data table below.

You will hang two masses (an example: 100 g) on two separate hangers. Choose your masses and angles; ensure that individual hanger should not exceed a mass of 250 grams. Fill out the table below using these values.

Force	Mass m [g]	Mass m [kg]	Magnitude mg [N]	Angle θ [°]	x-component [N]	y-component [N]
$\vec{A}$						
$\vec{B}$						
Resultant						

Then we can write the resultant and the equilibrant below

Force	Magnitude	Angle
Resultant		
Equilibrant		
Mass that you need to hang for this Equilibrant: _______________ g		

Step 2: now hang the masses for forces $\vec{A}$ and $\vec{B}$. Then apply the equilibrant force as you determined in your data table above.

<u>To check if the system is actually in equilibrium</u>, remove the central pin (at the center of the ring). If your system is actually in equilibrium, the ring will stay in place otherwise the masses will fall off in the direction on any net force.

Explain your observations.

Part II: Experimental Procedure III, Use Of Three Forces

Step 1: Calculation only. Do not hang any mass yet; you will do that in Step 2 after you finish your data table below.

You will hang three masses (an example: 100 g) on three separate hangers. Choose your masses and angles; ensure that individual hanger should not exceed a mass of 250 grams. Fill out the table below using these values.

Force	**Mass m [g]**	**Mass m [kg]**	**Magnitude mg [N]**	**Angle θ [°]**	**x-component [N]**	**y-component [N]**
$\vec{A}$						
$\vec{B}$						
$\vec{C}$						
Resultant						

Then we can write the resultant and the equilibrant below

Force	Magnitude	Angle
Resultant		
Equilibrant		
Mass that you need to hang for this Equilibrant: _______________ g		

Step 2: now hang the masses for forces $\vec{A}$ and $\vec{B}$ **and** $\vec{C}$. Then apply the equilibrant force as you determined in your data table above.

To check if the system is actually in equilibrium, remove the central pin (at the center of the ring). If your system is actually in equilibrium, the ring will stay in place otherwise the masses will fall off in the direction on any net force

Explain your observations.

____

____

____

Part IV: Wrap up and Lab End Checklist

1. Remove all masses and place them properly in the box/carrier. Double check to ensure no mass is left behind.

2. Remove all mass hangers.

3. DO NOT remove the central ring and strings.

4. Place your Force Table, masses, and strings back on the cart. Please take a moment to ensure that nothing is left behind.

5. If you have used a college laptop to do your calculations, do log out before you leave the lab.

What to include in your lab report:

(1) Your data tables and observations, comments, and analysis for three procedures you performed.

(2) Draw a free body diagram for the ring in each case.

(3) Explain why the forces on the central ring can be measured using the hanging masses.

(4) Names of lab partners and specific contributions each person made.

Where to submit the lab report: on Canvas

2: Alternative Vector Addition of Forces Lab

Learning Objectives

Use the force table to find the equilibrium force vector of two or more vectors.

2. Use analytical methods for determining the resultant force and equilibrium showing it on the force table.

3. Develop a better understanding of mass, vectors, forces, and weight.

Vectors, terms, and prior knowledge needed:

● **Equilibrium** - The force vector that can cancel out all of the other forces acting on a point

○ The force that causes this is called an equilibrant

● **Resultant vector** - The vector that is formed from the result of the combination of two or more vectors

○ $\vec{R} = \vec{A} + \vec{B}$

○ Vector R is the sum of the individual tension forces that the mass exerts on the string due to the acceleration due to gravity.

○ To get R the x-y components of vectors labeled A, B, and C are added together to get their respective component vectors, which are used to find the magnitude and angle of vector R.

○ With the magnitude and direction of vector R known, an equilibrant can be found by taking the direction angle of vector R and subtracting 180 degrees or by taking the inverse of the component vectors -$\vec{R}$=<-$\overrightarrow{R_x}$,-$\overrightarrow{R_y}$>.

● **Ideal Pulley** - A pulley that has no friction and does not restrict the movement of a string.

● **Newton's second law (F=ma)** - This lab is based on Newton's second law, Force=mass*acceleration. In this lab, force is the vector that results from the mass of the weights, and acceleration is due to gravity, so a will always be 9.8m/s^2.

Apparatus and tools:

Figure 2.1: Force Table

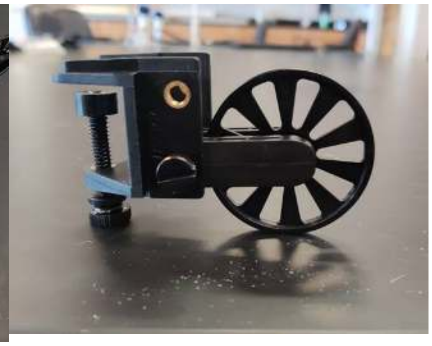


Figure 2.1: Pulley (super pulley or ideal pulley)

Figure 2.1:Pulley hangers (left) /Mass (right side top to bottom): 0.5g, 1g, 2g, 5g,10g, 20g, 50g, 100g :

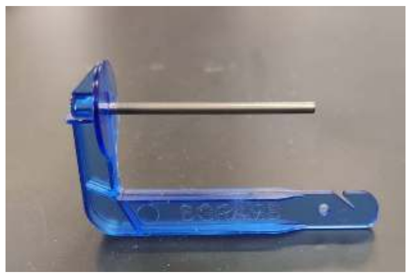
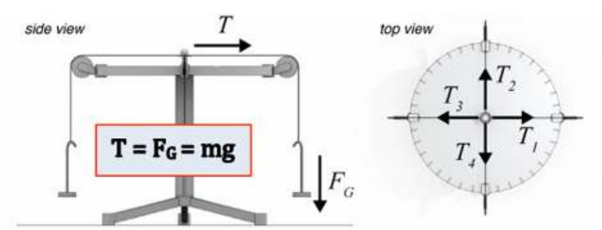


Figure 2.1: Pulley hanger:
This object has a mass of 5 grams, so consider that when calculating.

Force table introduction, explanation, and theory:

A force table is a simple setup that can be used to observe vector addition and equilibrium. You can attach one or more pulleys at the edge of the table, and hang a mass on a string that goes through this pulley and to the center connection of all the strings. These hanging masses exert a force downward on the string, and the string pulls back with equal force, called tension. The pulleys remove most of the friction force from the systems that would be introduced if the strings rubbed against the edge of the table. At the center of the table, all of the strings are connected by a ring or clear disk, at the center of that ring, there is a visual representation of whether the forces are in equilibrium. The central string connection is our object of interest, and where we will observe the effect of various forces on this ring. Changing the hanging mass, you can change the magnitude of the force felt by the center string connection. The table surface has labeled angles to set up vectors in specific directions. You can find more information online on how a force table works.

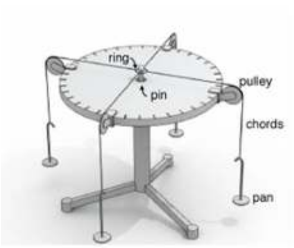


(image credit: CCNY CUNY)

If a mass “m” is hanging over the pulley, the mass has a force downward (the weight

of the mass is m*g, where g is the acceleration from gravity). And the tension on the string is upward. (The magnitude of the tension = m*g)

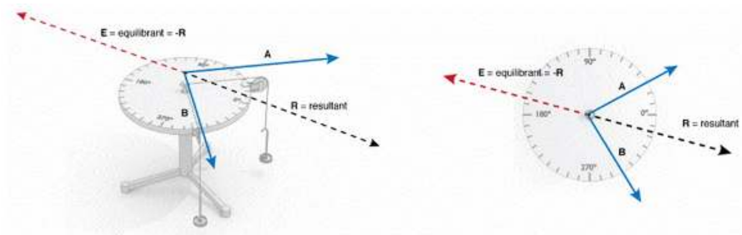
Set up the force table such that 0 degrees of the table protractor is on your right (just like +x-axis on a Cartesian coordinate system). This means 0° is +x, 90° is +y, 180° is -x, and 270° is -y on your coordinate system.



(image credit: CCNY CUNY)

Resultant vs. Equilibrant

Resultant force is the vector sum of the individual forces acting on the ring. The equilibrant is the force that brings the system to equilibrium.



(image credit: CCNY CUNY)

Force table operation

You will hang some mass on the hangers attached by a thread on the pulley. This means the weight of that mass is a force that has a downward direction, therefore doesn't have any other directional component that may disrupt the results of the experiment. However, the strings are attached at the center of the force table, and this means the tension force is proportional to the weight (*m*g*) of the mass used, which is a force acting on the central ring. This means you can set up one or more forces acting on the center connections of all the strings, and calculate their resultant force (resultant, R). Then you can determine what force (Equilibrant, E) would balance these forces to bring the system to equilibrium.

Pulley height adjustment

In the first image of this section, the string (highlighted by a red line) is connected to a pulley that is off the table surface, resulting in an inaccurate force measurement. In the second image of this section, the string (highlighted in red) is flat with the surface of the table. In the third image of this section is a green box highlighting the screw to connect to the table like in the first two images. Highlighted by a red circle is a screw that is used to adjust the arms of the pulley and therefore its height. The screw shown in the green box is used to connect the pulley to the force table to conduct the experiment.

Figure 2.1: Paste Caption Here

Precautions/tips:

1. Measure/note the mass of each hanger before you use it.
2. The force needed to balance the force table is not the resultant force but the equilibrant force, which is the inverse of the resultant.
3. Always calculate and check calculations before experimenting.
4. When using mass, take into account that the mass hangers are 5 grams.
   a. Ex: if you put a mass of 100 grams when doing your math add the mass of the pulley hanger of 5 grams, so the total mass is 105 grams.
5. Newtons (N) is measured with si units kilograms, meters, and seconds, not grams.

Experimental I (one force or mass and its Equilibrant):

Step 1: Calculation

do not hang mass yet. You will hang a mass (an example: 100 g) on the blue hanger. The angle should be 0°. Fill out the table below using these values. Remember to take the 5-gram hanger into account for the math.

Finding the resultant vector

Force	Mass [g]	Mass [kg]	Magnitude (mg) [N]	Angle θ [°]	X-component [N]	Y- component [N]
$\vec{A}$						
Resultant force vector =						

*Use kilograms for mass to write force in terms of newtons.

Taking the resultant force and changing it to the equilibrant vector.

Force	Magnitude	Angle
resultant		
Equilibrant		
Mass of the equilibrant force:		

Step 2:

Now hang the mass that creates force $\boldsymbol{A}$. Then apply the equilibrant force as you

determined in your data table above. To check if the system is actually in equilibrium, remove the central pin (in the force table shown, there is a clear circle at the center with a black circle on the table, which, when in equilibrium, will be aligned with each other). If your system is actually in equilibrium, the ring or clear disk will stay in place otherwise, the masses will be off in the direction of any net force.

Explain your observations

Experiment II (Two forces and their Equilibrant)

*Experiment II will be very similar to Experiment I, but you will have to calculate two masses instead of one.

Step 1: Calculation

Choose two masses to hang and insert into rows $\vec{A}$, and $\vec{B}$ then do calculations to find the Resultant force vector.

Force	Mass [g]	Mass [kg]	Magnitude (mg) [N]	Angle θ [°]	X-component [N]	Y- component [N]
$\vec{A}$						

Force	Mass [g]	Mass [kg]	Magnitude (mg) [N]	Angle θ [°]	X-component [N]	Y- component [N]
$\vec{B}$						
The resultant force vector =						

*Use kilograms for mass to write force in terms of newtons.

Taking the resultant force and changing it to the equilibrant vector.

Force	Magnitude	Angle
resultant		
Equilibrant		
Mass of the equilibrant force:		

Step 2:

Mimic experiment 1 step 2

Explain your observations.

Experiment III (Three forces and their Equilibrant)

*Experiment II will be very similar to Experiment I, but you will have to calculate two masses instead of one

Step 1: Calculation

Choose two masses to hang and insert them into rows $\vec{A}$ and $\vec{B}$ then do the calculation to find the Resultant force vector

Force	Mass [g]	Mass [kg]	Magnitude (mg) [N]	Angle θ [°]	X-component [N]	Y- component [N]
$\vec{A}$						
$\vec{B}$						
$\vec{C}$						
Resultant force vector =						

*Use kilograms for mass to write force in terms of newtons.

Taking the resultant force and changing it to the equilibrant vector.

Force	Magnitude	Angle
resultant		
Equilibrant		
Mass of the equilibrant force:		

Step 2:

Mimic experiment 1 step 2

Explain your observations

3: Conservation of Energy

Learning Objectives

To explore whether the principle of conservation of total mechanical energy of a system holds good by determining the gravitational potential energy, kinetic energy, and the total mechanical energy of a free-falling ball.

I. Introduction:

The purpose of this lab is to demonstrate the conservation of total mechanical energy. The principle of conservation of mechanical energy is that the total energy of an isolated system remains constant (i.e., if no nonconservative forces act on it). If a conservative force does act on a system the total energy remains the same but the kinetic and potential energy in the system may change individually. The equations that show the relationship between the total mechanical energy, kinetic energy and gravitational potential energy are listed below

$$E = KE + U \quad KE = \frac{1}{2}mv^2 \quad U = mgh \tag{3.1}$$

Symbol
E= Total Mechanical Energy
U= Gravitational Potential Energy
g= acceleration of gravity (9.8)
m = mass
h= height of the object from a level of r

This lab will make use of an ultrasound sensor that will record the position and velocity of a falling object. The recorded data can then be used to calculate the mechanical energy, kinetic energy and gravitational potential energy of the falling object. With the use of a spreadsheet those calculations can then be plotted into a graph showing the constant total energy can change in kinetic and potential energy over time.

II. A summary of the method

1. Use a motion sensor to measure the position and velocity of a falling basketball over a period of time.

2. Copy the measurement on a spreadsheet.

3. Calculate the kinetic energy, gravitational potential energy, and total mechanical energy and plot them as a function of time.

4. Analyze your graphs to determine whether the mechanical energy of this system was conserved.

III. Apparatus

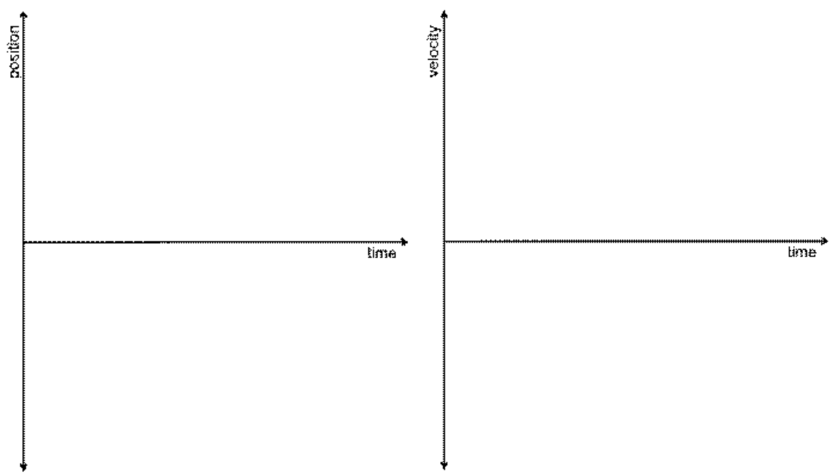
What	Why
A computer with Vernier LoggerPro software. (or a Vernier LabQuest Mini LabQuest2 or LabQuest3 data logging solution). and a spreadsheet	To control the motion sensor and record data
Spreadsheet (Excel or Numbers or OpenOffice etc.)/ Google SHEETS	Data analysis
Vernier Go! Motion Sensor	To measure position and velocity as function of time
Basketball	To be used as the object in a free-fall motion
Metal wire cage	To protect the motion sensor from the falling ball

What	Why
Wood blocks	To raise the motion sensor above ground within the metal cage and minimize the recording of signal reflected from the cage.
Step stool	To drop the ball from a greater height or to climb on the table

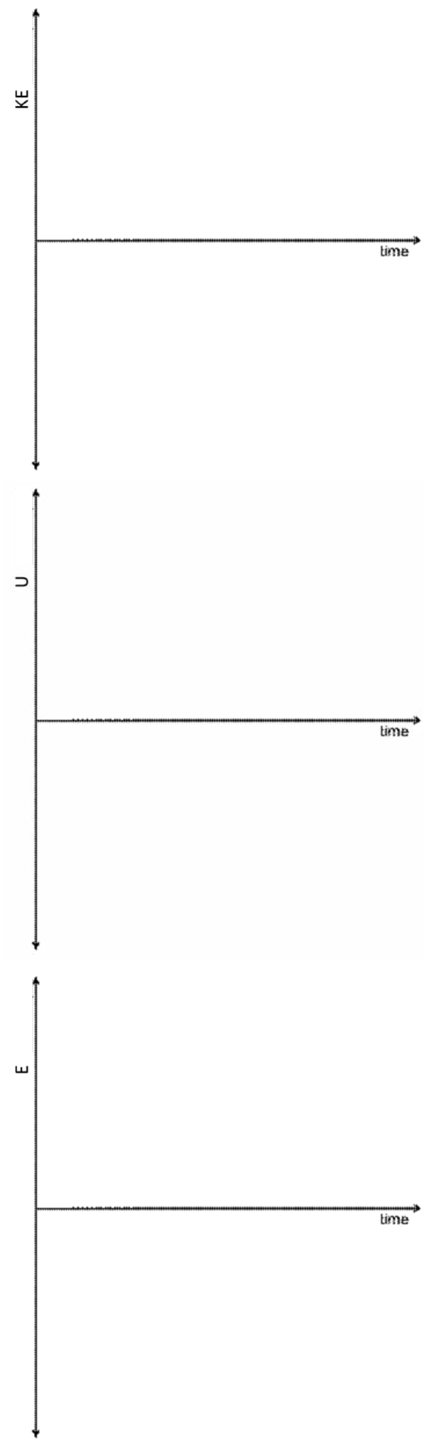
> **Note**
>
> 1. Units of all physical quantities are important. ALWAYS.
> 2. Read the instructions.
> 3. It is important to focus on achieving good quality in your experiment and data set. Repeat the experiment as many times as needed until you are satisfied with your work and can explain what you observe. You can work with your lab partners outside the classroom to finish the lab report at home (you have one week's time).
> 4. Ask for help (if/as needed) in step 3 of the "PROCEDURE"
> 5. The laptop that is connected to your experimental set up should only be used for the experiment. Do not use it for anything else during the experimental run.
> 6. The Go! Motion sensor is sensitive and will record any movement near its line of sight. So it is important to stay away from it and keep other movements to a minimum when the sensor is recording measurements.

IV. Conceptual Understanding

Sketch Your Predictions for the Motion Graphs. Before doing the experiment with the falling basketball, imagine that it is held high above the ground and released from rest so that it falls vertically toward the ground. Discuss with your partners what the *position vs. time*, *velocity vs. time*, and *acceleration vs. time* plots should look like. Ignore any rebound. Sketch each of your predicted plots on the graphs below using a *dotted line*. Please do not change your predictions after seeing the actual motion plots.



Now, also draw your predictions for the Kinetic (KE), Gravitational Potential (U) and total mechanical energy (E).

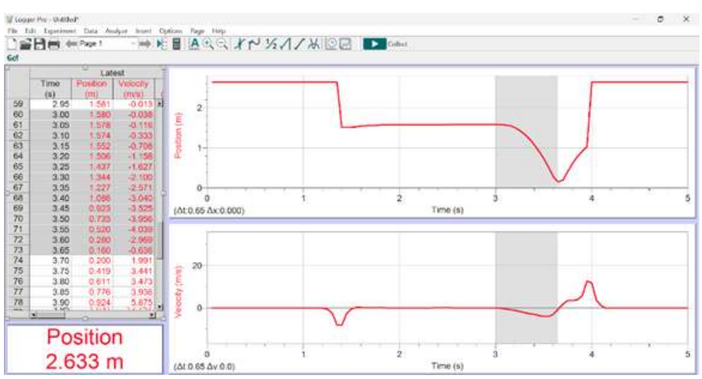

KE
time
U
time
E
time

V. Procedure

We will do the analysis on a spreadsheet. You have two options: create your own spreadsheet (highly recommended) or use the provided spreadsheet and copy your data on it.

1. Measure the mass of the basketball and record it here (you can record directly on your spreadsheet if you want).

   Mass of the basket ball: _______________ g = ______________ kg
2. Prepare the Vernier Go! Motion sensor. If you flip open the sensor plate, you will see two options. Switch the button to to the "walking/ball" option. Add photo
3. On the ground place both blocks (either on top of each other or side by side vertical) and then place the motion sensor on top the blocks. Secure the blocks and the motion sensor on the floor with tape to minimize movement. Ensure that there is still access to the output port on the Go! Motion sensor.
4. We will first test that all components are working before placing the wire cage on top of the motion sensor and securing it to the ground with a tape.
5. To test: thread the motion sensor cable through the wire cage and connect it to the motion sensor (keep the cage on the side and not on top of the sensor yet). Connect the other end of the cable to the computer.
6. Open the Logger Pro software on the computer. If all components are connected properly, the Logger pro Program should detect the device and setup appropriate graphs and tables. A small green light will also turn on the Go! Motion. Below is that the Logger Pro window should display:
7. Place the basket over the motion sensor. Ensure that the wire basket does not obstruct the motion sensor. Test this by going on Logger Pro and triggering the sensor by clicking on the "green arrow" at the top of the Logger Pro display. The Go motion should emit clicking sounds and data should populate the graphs and tables on Logger Pro. The position of a hand wave or other moving item should be reflected on the graph when the device is on and running. Now secure the cage to the ground using tape. Do note that when the sensor is running, the "green arrow" turns into a "red square" and that can be used to stop the sensor any time.
8. Now you are ready to run your experiment.
9. With the help of a step stool have a participant raise and hold the basketball at some height (~ 2 m) directly above the motion sensor. Once your team is ready, trigger the Go! motion and have the participant drop the ball. The sensor will automatically stop when finished or you can stop it any time by clicking on the red "stop" button.
10. Logger Pro should display the data on its table as well as graph. Observe the graph and identify the region of the position vs. time and velocity vs. time curves that correspond to the free-fall motion of the basket ball. Do note that we must focus only on the free-fall and therefore, we must ensure that we do not include the data points before the fall or after the ball bounces back from the ground. The graph below (experiment run by Jenand Joseph on 07/23/2024) shows an experimental run.



10. The region of the curves highlighted in grey corresponds to the free-fall motion. Notice that when we highlight the curve, the corresponding data values in the table are also highlighted. That is the dataset we need to copy from the table for our analysis on spreadsheet.
11. Repeat the experiment by dropping the ball and collecting data. Try to create smooth slopes on the graph for better accuracy. When you are satisfied with your experiment, copy the data and paste it in your spreadsheet. Do it for at least three trials.

VI. Analysis

If you are using the sample spreadsheet provided here, follow the instructions therein. It will automatically create and display the graphs that you can then analyze.

If you are creating your own spreadsheet, make sure to have a cell for the mass of the basketball. Also create three columns where you can record the time, position, and velocity data you copied from Logger Pro. You will need to make three calculated columns for the gravitational potential energy, kinetic energy, and total mechanical energy.

For each experimental trial:

1. Enter the mass of the basketball in a cell (use the data in any specific unit system. Here we are using the SI unit)
2. With the Logger Pro data collected in a spreadsheet, such as EXCEL or Google SHEETS (or any other spreadsheet), organize the data. Have a cell dedicated for the mass of the basketball and have labels for each trials data for Time, Position and Velocity.
3. Create 3 new columns beside the data labeled as Kinetic Energy, Potential Energy and Total Energy.
4. Potential energy: on the first cell of this column, calculate the gravitational potential energy using the equation from the Introduction section of this document.
5. Kinetic energy: on the first cell of this column, calculate the kinetic energy using the equation from the Introduction section of this document.
6. Total energy: calculate this as the sum of the potential and kinetic energies.
7. Once you have calculated the top cell of each of these energies, copy the calculations for the rest of the cells for each column. An example of a dataset is shown below (Jenand Joseph, 07/23/2024)
8. Then graph the Kinetic, potential, and total energies as function of time. The simplest way to see the details is a scatter graph with a smooth line joining the data points.

Mass [kg]	Time [s]	Position [m]	Velocity [m/s]		Kinetic Energy [J]	Potential Energy [J]	Total Energy [J]
0.496	3.000	1.580	-0.038		0.000	7.683	7.684
	3.050	1.578	-0.116		0.003	7.678	7.681
	3.100	1.574	-0.333		0.027	7.657	7.685
	3.150	1.552	-0.708		0.124	7.551	7.675
	3.200	1.506	-1.158		0.333	7.326	7.658
	3.250	1.437	-1.627		0.656	6.989	7.645
	3.300	1.344	-2.100		1.094	6.535	7.629
	3.350	1.227	-2.571		1.640	5.966	7.606
	3.400	1.086	-3.040		2.292	5.283	7.575
	3.450	0.923	-3.525		3.082	4.492	7.574
	3.500	0.735	-3.956		3.880	3.575	7.455
	3.550	0.520	-4.039		4.046	2.527	6.573
	3.600	0.280	-2.969		2.186	1.362	3.548
	3.650	0.160	-0.636		0.100	0.779	0.879

A graph is shown below

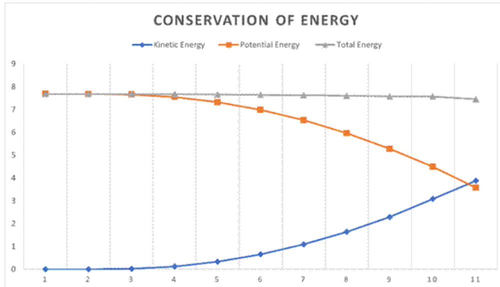


Figure 3.1: Copy and Paste Caption here. (Copyright; author via source)

9. Do the calculations for each of your experiment trials.

The concepts of gravitational potential energy, kinetic energy and conservation of energy.

a. **What did you observe during this lab** – explain with relevant equations used to calculate the different forms of energies (unless you already did that in part (a).
b. What should happen to the potential and kinetic energies as the ball is dropped from a certain height? Does your experiment support your understanding?
c. What happens to the total energy of the basketball? Elaborate your answer.
d. Did this simple experiment demonstrate the principle of conservation of energy? If yes, explain why you came to this conclusion. If no, explain what factors may have caused any discrepancy.
e. What results would you expect if you had used a coffee filter instead of a basketball?
f. Your lab report must contain the names of your team members. You must also specify in one or two sentences what each person contributed specifically (yes, you worked together but what was contributed by each person).

Note: these questions will be best answered after you have finished the experiment and data analysis as explained next.

4: Acceleration Due to Gravity

Learning Objectives

To learn, understand, and visualize how the acceleration due to gravity affects falling objects

Method:

The method we will use takes data from an ultrasonic sensor on the velocity, position, and acceleration of an object in front of it. The computer creates graphs of each quantity on a computer software tool. For most objects, the acceleration should roughly match -9.8 m/s as this is the acceleration due to gravity. But it may not always be the case, and that is what you are exploring now.

Set up:

To set up this lab experiment, we have to protect the sensor. We accomplish this by putting a metal cage or basket around the sensor and taping it to the ground (4.2). This allows the object to fall towards the sensor while not directly impacting the sensor, this also allows the sensor to see through the cage to record the data. We also need to raise the sensor up to the ceiling of the cage. This is so the cage will not be detected by the sensor, and the sensor will only detect the falling object. We do this by placing two wood blocks and taping the sensor on top of those blocks (Figure 4.1). We also need to connect the wire from the sensor to the computer. To do this, pass the wire through any one of the holes of the cage so that the bottom of the cage remains flat. Also, to make use of the gaps in the cage the sensor was centered on the hole (the gold circle) to ensure the least amount of interference.

Figure 4.1

Figure 4.2

Vernier LoggerPro is the software that is used to retrieve data from the sensor. To start collecting data, press “Collect” in the software. When the sensor is in the process of collecting data, there will be a clicking sound, and the graph will show the data being collected.

To ensure that the sensor is working hold an object close to the sensor after pressing “Collect” in the software. While doing this, make sure the object is far enough away as there is a minimum distance (20mm) where the sensor can not see.

Procedures:

First, hold the object over the sensor and cage as shown in 4.3. Then start the sensor reading and drop it over the sensor and cage at the same time. Be sure to raise it to a height where the sensor can see it as it is falling, but also not too high where it is completely out of range of the sensor.

You will diffrent drop objects onto the sensor, which will record its position, speed, and acceleration. For example a ball, frisbe, and a coffee fillter of which the ball is shown.

Figure 4.3

Analyzing the graph:

Only a small portion of the graph will be of the ball's free fall, so you will have to identify where that is on the graph. Understanding the relationship between position, velocity, and acceleration can help when analyzing the graph, as by default, the software shows the graph of position over time and velocity over time.

To find the rate of change, look at the velocity graph, find the slope of the section of the falling object, and then that will give you the acceleration. Use the software's built-in linear fit analysis to show the rate of change of a linear line between two points in time of the velocity graph which is acceleration. To use this analysis feature, press analyze located at the top right of the software window a drop-down menu will appear. Find the two points on the time-axis of the object's free fall that you want to analyze, and it will find the slope of that section, giving you acceleration.

Velocity (m/s)	acc (m/s^2)	Time (s)
-0.004	-0.094	0.16
-0.009	-0.114	0.18
-0.010	-0.047	0.2
-0.009	-0.029	0.22
-0.009	-0.087	0.24
-0.015	-0.040	0.26
-0.015	0.165	0.28
-0.007	0.328	0.3
0.002	0.311	0.32
0.008	0.155	0.34
0.006	0.104	0.36
0.007	0.242	0.38

Velocity (m/s)	acc (m/s^2)	Time (s)
0.017	0.286	0.4
0.033	-0.372	0.42
0.011	-1.613	0.44
-0.028	-3.223	0.46
-0.103	-5.556	0.48
-0.251	-7.783	0.5
-0.433	-9.055	0.52
-0.628	-9.491	0.54

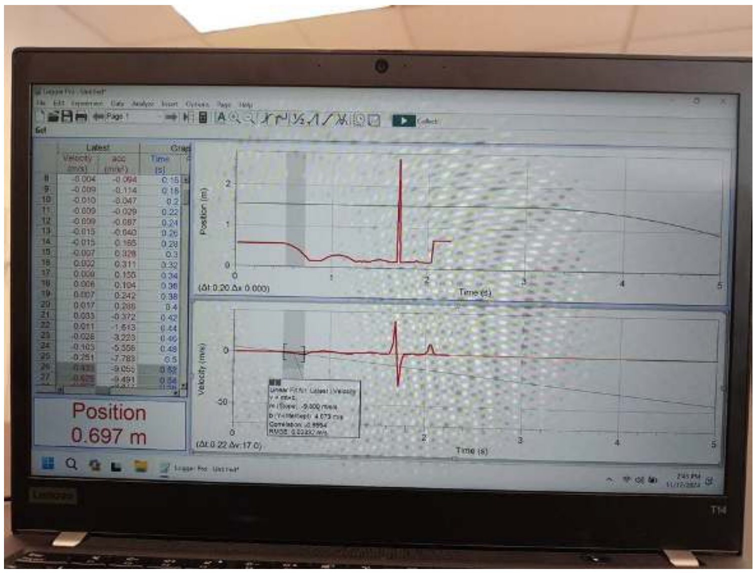


Figure 4.3:

Certain objects with different characteristics will feel the same acceleration, but when graphing their velocity and acceleration, they will show up differently. This is because the air resistance force is greater than the force of gravity pushing it down at sertan speeds. Things like weight and surface area can affect the speed at which an object will fall. This is called terminal velocity, which is the maximum speed that an object can fall on earth

In this lab you were able to compare the properteis of different objects under the influence of earth's gravity.

Index

Glossary

Sample Word 1 | Sample Definition 1

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  - 2: Alternative Vector Addition of Forces Lab - *Undeclared*
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  - 4: Acceleration Due to Gravity - *Undeclared*
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    - Table of Contents - *Undeclared*
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