CNS Institute for Physics Teachers

Title:	**Playing in Newton's Lab**
Original: **Revision:**	June 15, 2010
Authors:	Buzz Putnam
Appropriate Level:	Regents, Honors Physics
Abstract:	There are many misconceptions for students in the world of Physics and one of the most common is the relationship between weight and mass. Throughout a student's high school science courses, the terms, Mass and Weight, are used by educators without regard to their actual conceptual meanings and the two become a "gray" area in the students' mind. This confusion between Weight and Mass is carried with the student throughout high school until he or she enrolls in a Physics course, where the distinction is made between the two terms. In this lab, the student will determine the Mass of objects utilizing three different methods without the conventional "weighing" technique that is the usual protocol for finding Mass in the Physics classroom. Using Newton's 1st and 2nd Laws, the Mass of the object(s) will be found by student experiment, rather than using a Newton scale. As a 4th exercise, students will use a hands-on technique to conceptualize Newton's Law of Universal Gravitation.
Time Required:	Two 40 minute class periods

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NY Standards Met:	*Key Idea 2:* Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. S2.1 Devise ways of making observations to test proposed explanations. • design an experiment to investigate the relationship between physical phenomena S2.4 Carry out a research plan for testing explanations, including selecting and developing techniques, acquiring and building apparatus, and recording observations as necessary. (*Note: This could apply to many activities from simple investigations to long-term projects.*) *Key Idea 5:* 5.1 Explain and predict different patterns of motion of ix. verify Newton's Second Law for linear motion 5.1i According to Newton's First Law, the inertia of an object is directly proportional to its mass. An object remains at rest or moves with constant velocity, unless acted upon by an unbalanced force. 5.1j When the net force on a system is zero, the system is in equilibrium. 5.1k According to Newton's Second Law, an unbalanced force causes a mass to accelerate*. 5.1q According to Newton's Third Law, forces occur in action/reaction pairs. When one object exerts a force on a second, the second exerts a force on the first that is equal in magnitude and opposite in direction.
Special Notes:	Teachers must observe height his lab requires the riding of scooter in hallways.

Behavioral Objectives:

Upon completion of this lab a student should be able to:

- Understand that Mass can be found through indirect measurement.
- Distinguish between the concepts of Mass and Weight.
- Understand the relationships and correlations between Inertia and Mass.
- Develop an understanding of Newton's laws and how they apply to Mass and Force.
- Develop an understanding of Newton's laws and how they apply to Acceleration and Force.
- Develop an appreciation for Newton and the relationship between his encompassing Laws of nature.

Class Time Required:

- Two – 40 minute periods

Teacher Preparation Time:

- For Part I, ***"The Mass of the Unknown Apple"***, the set-up requires, clamps, various masses, the Inertial balance, a stopwatch and an Unknown Apple. Set up time is 10 minutes for 12 stations.
- For Part II, ***"Newton's Scooter"***, the set-up requires a Razor scooter, a stopwatch, a bathroom scale and the LASER photogate apparatus. Set up time is 5 minutes for all groups.
- For Part III, ***"Mass Confusion"***, the set-up requires a Friction block and a Newton PUSH scale. Set up time is 5 minutes for all groups.
- For Part IV, ***"Newton's Universal Gravity Simulation"***, the set-up requires a light/LASER combo and a ruler. Set up time is 10 minutes for all groups.

Assumed Prior Knowledge of Students:

- Students should have a working knowledge of Newton's Laws prior to or in conjunction with this lab.
- Students should be familiar with $F=ma$, $F_f = \mu F_n$ and $F_g=Gm_1m_2/r^2$ and be able to manipulate the equations to calculate unknown variables of Mass, Force and Acceleration.

Background Information for Teacher:

- This lab may be accomplished as a whole or in parts (I-IV) as seen most beneficial with their students. As a whole, this lab would serve as an excellent review of Newton's Laws and the relationship to real-life situations. If the teacher teaches Newton's Laws sequentially, the lab can be partitioned and utilized as the Laws are presented. Four labs could be presented to the student as the concepts are taught throughout the Newton's Laws section of the course.

- The teacher should have complete conceptual knowledge of qualitative and quantitative mass determinations using Newton's 3 Laws. Keep in mind that this lab illustrates various applications of Newton's Laws relating to real-life situations. Results may lead to some deviation from the ideal conditions and "perfect" answers in this lab.
- Teachers should attempt the lab prior to using it with students to find any variables that may lead to the students' results not being as predicted. For Part II, ***"Newton's Scooter"***, students who have a higher mass tend to achieve more accurate results in determining their mass. It is more difficult for students to maintain a CONSTANT applied force on a smaller student (less mass) than it is on a student with high mass.
- This lab has been tested through many Regents-level classes with excellent results. A meticulous pre-lab is essential for maintaining consistency between all student groups.

Answers to Questions:

1. Yes. Gravity does not affect the Period of the Inertial Balance.
2. Yes. Microgravity does not affect the Period of the Inertial Balance.
3. The Inertial Mass is the same. Mass is not altered by gravitational fields.
4. In a gravity-free environment, you may "shake" the containers or apply an equal force to both containers and you will be able to sense the differences in mass. If both containers were moving at you at the same velocities, the impact force would be felt and you would be able to distinguish between the two containers.
5. No force is required since the cannonball would continue to move with a constant velocity in a straight line due to the Law of Inertia.
6. In a gravity-free environment, if the mouse and elephant were moving at you at the same velocities, the impact force would be felt MORE by the elephant than would the mouse. The mouse would be easier to stop due to the lower mass and Inertia.
7. As the Earth rotates about its axis and you are in a helicopter in Washington, D.C., you are moving with the Earth's rotational speed. Ascending off the ground will not alter your inertia and therefore you will still be moving with the Earth's rotational speed.
8. Answers vary… Timing errors, pulling back the balance too far to cause unneeded vibration, miscounting the # of periods, etc.
9. The graph's trendline will be a straight line and demonstrates that Period and Mass for the Inertial Balance is a direct relationship.
10. A constant unbalanced force produces acceleration.
11. The acceleration will be constant given the same mass and a constant applied force.
12. As mass increases, the acceleration of the object will decrease.
13. If mass is constant, as the applied force increases, the acceleration of the object will also increase. It is a direct relationship.
14. 3.2 m/s^2. Cos $40^o = F_h/150N$ => 115N-35N=80N => 80N=25kg(a)
15. 10N. F(0.01sec)=(0.02kg)(0m/s-5m/s)

16. $3.7 m/s^2$. $F_f=(0.3)(150N) \Rightarrow F_{net}=100N-45N \Rightarrow 55N/15kg=3.7 m/s^2$
17. Answers will vary… By slowly applying a force to the block on the level lab table with the Push-Scale, one can find the Force of Static Friction between the wood block and the wood surface. Once the value is determined, the lab team can use the $F_f=\mu F_n$ to determine the F_n which will result in the equal F_g for the block. From $F_g/m=g$, the mass of the block can be calculated.
18. Diagrams will vary.
19. After calculating the mass of the Friction Block, the actual mass is known and % Error can be calculated using the equation "actual mass-experimental mass/actual mass X 100".
20. ~4m. $6 \times 10^{-10}N=(6.63 \times 10\text{-}11 Nm^2/kg^2)(12kg)(12kg)/r^2$
21. Answer should be ~4m with a margin of error.
22. Answer should be that the two values agree.
23. $1.5 \times 10^{-10}N$
24. $2.4 \times 10^{-9}N$
25. $2.4 \times 10^{-9}N$
26. Answer should be that the two values agree.
27. Graph should resemble an "Inverse-Squared" relationship.
28. $y=1/x^2$
29. Answer should be that the two graphs of "Inverse-Squared" relationships agree.
30. Answer should be that the area of the flashlight circles and the "Inverse-Squared" Law agree.
31. Graph should resemble an "Inverse-Squared" relationship.
32. Since Gravitational forces obey the $y=1/x^2$ "Inverse-Squared Law", in theory, there is no place in the universe to ever measure the F_g to be zero.
33. 3/16 times as much force as the original set-up. Use $F_g = G\frac{m_1 m_2}{r^2}$ to explain your answer.

34a. Answer "D".

34b. Since a Black hole is a collapsed star and the masses (m_1 and m_2) of the objects remain constant AND the distance between the centers (r) is unchanged, the earth will remain in orbit around the Black Hole. Aliens observing us would see an Earth revolving around "nothing"!

Equipment List

10

1 8 5 9

3 4

6

3

4

7

2

Item Number	Quantity	Item
1		
2		
3		
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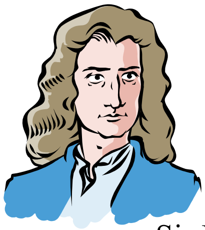
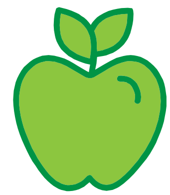


PLAYING IN NEWTON'S LAB

Sir Isaac Newton's 3 Laws of motion involve the aspects of Mass, Force and Acceleration and their relationship to each other. The concept of Mass is a constant theme throughout his 3 laws of motion and misconceptions about Mass, Weight and Force spawn confusion when learning about Newton's Laws. This lab will offer students several indirect methods of measuring Mass using Newton's Laws, rather than the traditional textbook homework problems. Following completion of the lab, which is divided into 4 parts, students will understand the differences and similarities between Mass, Weight and Force.

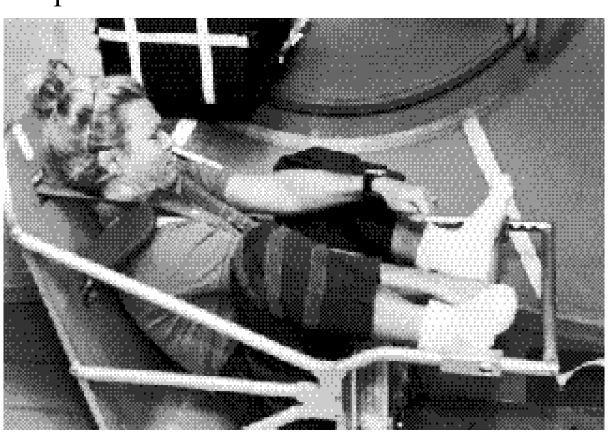


Part I: <u>The Mass of the Unknown Apple</u>

<u>Introduction</u>

In Part I, you are going to find the Relative Mass of an object WITHOUT measuring it with an electronic balance, a triple-beam balance or a spring scale using Newton's 1st law. By placing a known mass on an Inertial Balance and vibrating the pan, the length of time the balance takes to oscillate back and forth (Period) is recorded. The results of Period vs. Mass are plotted on a graph and finally an unknown mass is placed on the pan, measuring its Period. By referring to the graph, students will be able to determine the unknown object's Relative Mass by seeing where it falls on the graph. If desired, the balance could be calibrated in kilograms by measuring the test masses on an electronic balance.

An Inertial Balance is used in the International Space Station and on the Space Shuttle to determine the masses of astronauts in microgravity, where conventional scales fail to work. Placing an astronaut on a typical bathroom or spring scale will not cause the scale springs to compress. Setting a sample on one side of a beam balance will not affect the other side. This causes problems for researchers. Life science studies on the nutrition of astronauts in orbit require daily monitoring of an astronaut's mass. In materials science research, it may be necessary to determine how the mass of a growing crystal changes daily. Using the method in this lab, we can measure mass without gravity's effect on the sample.



Payload Commander Dr. Rhea Seddon is shown using the Body Mass Measurement Device during the Spacelab Life Sciences 2 mission. The device uses the property of inertia to determine mass.

Photo courtesy of:
http://quest.nasa.gov/space/teachers/microgravity/4inert.html

Materials:

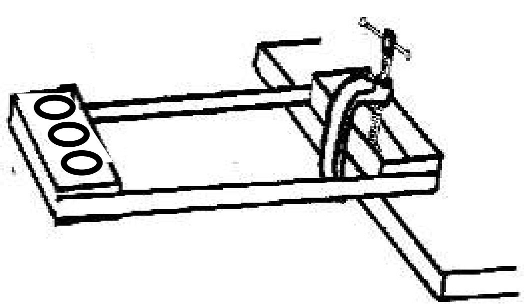
- 6 Inertial Balances with test masses
- 6 c-clamps
- 6 stopwatches
- 6 Unknown "Newton's Apples" (Each "apple's" Mass will be different for every lab group)

Instructions and Procedures:

- Clamp the Inertial Balance to the lab table as shown in the diagram on the following page.
- Using the Inertial Balance set-up and the procedures as instructed, each lab group will find the Relative Mass of their *Unknown Newton's Apple*.
- You must measure the **PERIOD** [one complete back and forth motion] of the balance without any masses on the Inertial Balance. Since one period is very difficult to measure, you must count the Number of Periods for 10 seconds. This is the **Frequency** of the balance. Enter your value for Frequency in Data Table #1.

* DO NOT PULL BACK THE APPARATUS TOO FAR AS IT CAN ALTER YOUR RESULTS!

- Now place a black mass (We will call the black masses… "Cores") into one of the holes in the pan.
- Again measure the **Frequency** by counting the number of periods for 10 seconds. Enter your value for Frequency in Data Table #1.
- Continue the procedure by adding a second black mass into one of the remaining holes in the pan. Again measure the **Frequency** by counting the number of periods for 10 seconds. Enter your value for Frequency in Data Table #1.
- Add the third black mass into the remaining hole in the pan. Again measure the **Frequency** by counting the number of periods for 10 seconds. Enter your value for Frequency in Data Table #1.



Data Table #1

Trial #	***Relative Mass* "Cores"**	***# Periods for 10 seconds***	***Frequency* (# of Periods/Second)**	***Period* (# of Sec/Period)**
1	**No load on balance**			
2	**Mass #1**			
3	**Mass #2**			
4	**Mass #3**			

- Complete Data Table #1 and determine the **Period** for each trial.
- Create a graph in Excel for **Relative Mass (x-axis) vs. Period**. Be certain to label the axes, Lab Title and best-fit trendline.
- **After** completing the Period vs. Relative Mass graph, affix the flat platform onto the Inertial Balance.
- Place the *Unknown Newton's Apple* ("toy apple") on the Inertial Balance and secure it with the rubber bands provided.
- Using the same method as in the lab, find the **Period** of *Unknown Newton's Apple*.
- Using the information on the graph, determine the Relative Mass of the *Unknown Newton's Apple* by locating where its Period is located on the trendline.

  Relative Mass (…in "Cores") of your *Unknown Newton's Apple* → ______________________________

- Select one of the **Known Masses** from the teacher's desk and secure it to the Inertial Balance. Using the same method as in the lab, find the **Period** of the known mass.

  Known Mass (kg) → ______________________________

  Period of your **Known Mass** → ______________________________

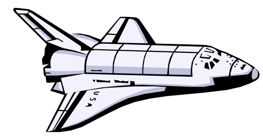
- Using your graph, find the **Actual Mass** of your *Unknown Newton's Apple* (in kg).

  Actual Mass of your *Unknown Newton's Apple* →______________________________

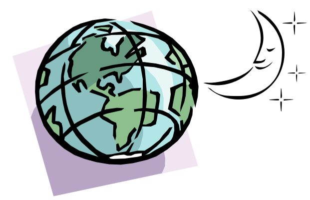
Lab Questions:

1. Could this lab be performed with the **same results** on the Moon?

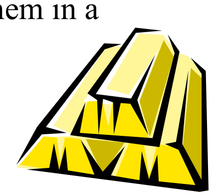
2. Could this lab be done with the **same results** on the Space Shuttle?



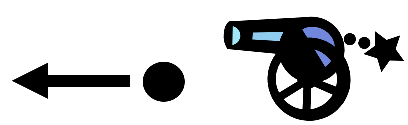
3. Where do you have **greater INERTIAL MASS**: on **Earth** or on the **Moon**?



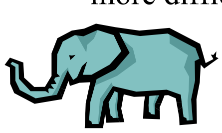
4. Two closed containers look exactly the same but one is filled with gold and the other is filled with feathers. How will you able to tell the difference between them in a "gravity-free" environment?



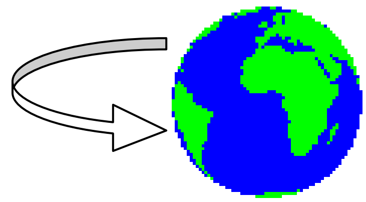
5. If you were in a spaceship and fired a cannonball into frictionless, gravity-free space, how much **force** would have to be exerted on the cannonball **to keep it going** at a **constant velocity**?



6. An elephant and a mouse are in a "gravitation-free" environment. Using your ideas of Newton's 1st Law, when they moved toward you with the SAME velocity, would it be more difficult to stop the elephant, mouse or no difference?



7. As the Earth rotates about its axis, you are in a helicopter in **Washington, D.C.** **Why** couldn't you simply ascend above Washington, D.C., hover in the helicopter for three hours as the Earth rotates at 1000 miles/hour below you and wait until San Francisco passes below you, then descend into San Francisco? Explain using Newton's 1st Law in your answer.



8. What are some of the possible sources of error in measuring the Period of your masses?

9. What does the trend line in your graph illustrate?

Part II: Newton's Scooter

Introduction:

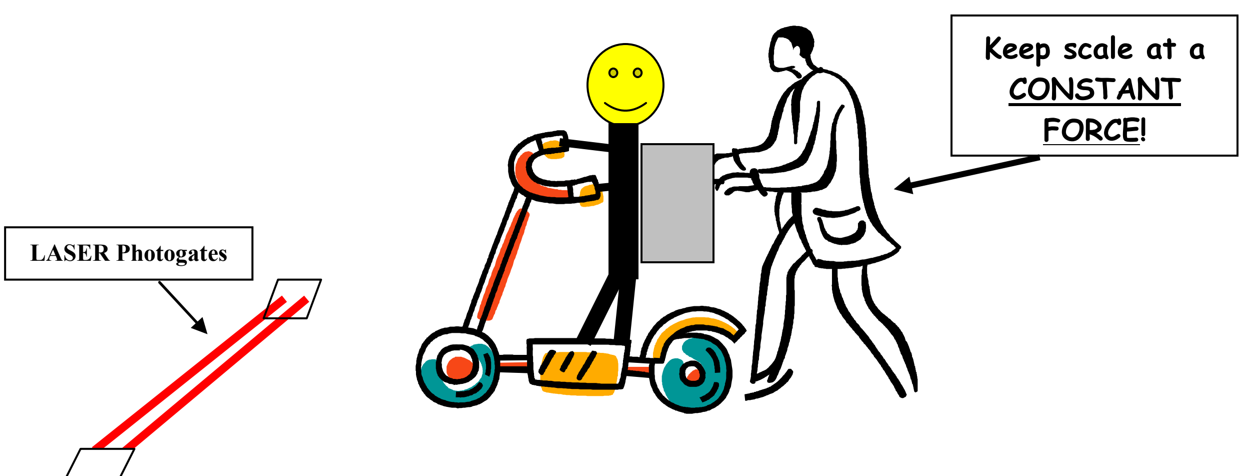
In Part II, you are going to find the **Actual Mass** of an object WITHOUT measuring it with an electronic balance, a triple-beam balance or a spring scale using Newton's 2nd law. Using only the **Acceleration** and a **Constant Applied Force** of the rider on a scooter, you will be able to determine the Mass of a rider without direct measurement. Newton's 2nd law states that when a constant unbalanced force is applied to an object, the object will accelerate in the direction of the net force.

Materials:

- *Razor* scooter
- bathroom scale (lbs or Newtons)
- calculator
- stopwatches
- LASER photogate timer

Instructions and Procedures:

- In teams of 3 students, each team will select a Rider, a Timer and a "Force Pusher" for the lab.
- The rider will line up at the starting line in the science hallway.
- Using a bathroom scale, the "Force Pusher" will push the rider with a Constant Force throughout the experiment. It is VERY IMPORTANT that the Force be held Constant throughout the trial! If the Force does not remain constant (ie. The bathroom scale reads the same force reading through the entire push), the resulting calculated mass will not be accurate.
- In starting the experiment, the timer will start the rider-pusher team and the stopwatch simultaneously.
- The pusher will begin applying a constant Force with the bathroom scale on the rider. (See schematic below) Apply the Force throughout the entire distance and release the rider only after passing through the LASER photogate..
- Begin by applying 10 lbs. of Force and add 10 lbs for each successive trial.



- Record the <u>Force Applied</u>, the <u>Time</u> of travel and the <u>Final Velocity</u> in the <u>Data Table #2a</u>.
- Change lab assignments and repeat this for EACH member of the Team. (Use Data Tables 2b and 2c.) Your teacher may direct you to use the same rider throughout all three trials or one trial for each team member. In either case, exchange lab responsibilities if possible.

<u>Data Table #2</u> - Rider #1

Trial #	Force (lbs) **F_{net}**	Force (Newtons) [1 lb = 4.45N] **F_{net}**	Initial Velocity **V_i**	Final Velocity (from photogate) **V_f**	Time **t**	Acceleration **a**	Mass **kg**
#1							
#2							
#3							

<u>Data Table #2</u> -Rider #2

Trial #	Force (lbs) **F_{net}**	Force (Newtons) [1 lb = 4.45N] **F_{net}**	Initial Velocity **V_i**	Final Velocity (from photogate) **V_f**	Time **t**	Acceleration **a**	Mass **kg**
#1							
#2							
#3							

<u>Data Table #2</u> - Rider #3

Trial #	Force (lbs) **F_{net}**	Force (Newtons) [1 lb = 4.45N] **F_{net}**	Initial Velocity **V_i**	Final Velocity (from photogate) **V_f**	Time **t**	Acceleration **a**	Mass **kg**
#1							
#2							
#3							

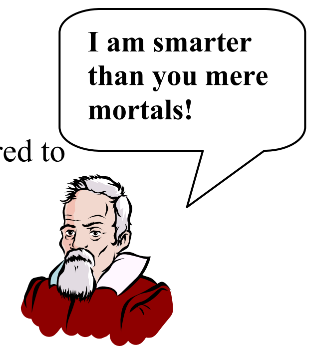
- After **CALCULATING** the mass of each rider, use the **KILOGRAM** bathroom scale to find the rider's measured Mass. Compare the **CALCULATED MASS** to the **ACTUAL MEASURED MASS** of each rider. Complete Data Table #3.

$$\frac{\text{ACTUAL MASS - CALCULATED MASS}}{\text{ACTUAL MASS}} \times 100 = \%\ \text{ERROR}$$

Data Table #3

	Actual Measured Mass	**Calculated Mass**	**% Error**
Rider #1			
Rider #2			
Rider #3			

Lab Questions:



10. Until the time of Galileo, people believed that a **constant force** was required to produce a **constant speed**. What does a constant force produce?

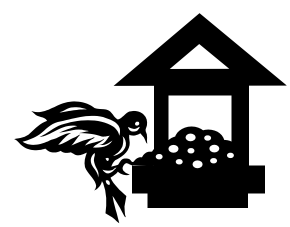
11. What happens to the **Acceleration** as the rider proceeds farther and farther down the race track?

12. With a **Constant Force** applied to the rider, what is the relationship between **Acceleration** and **Mass**?

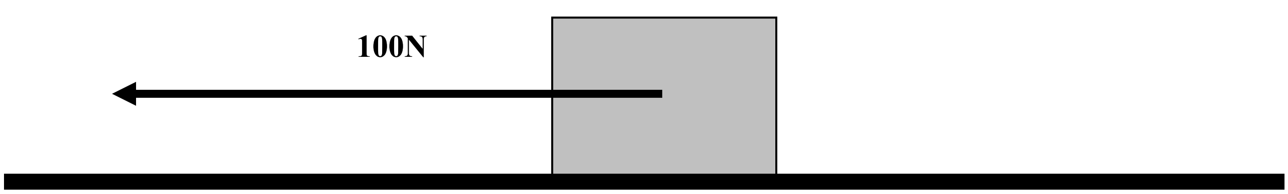
13. If the **Mass** of the rider is *unchanged*, what is the relationship between **acceleration** and **Force**?

14. In pushing a **25 kg** lawn mower, Lois exerts a Force of **150 N** on the handle at **40^o** to the ground. With a Friction Force of **35 N** caused by the wheels and wet grass, find the **Acceleration** of the lawnmower. (**Draw** ALL Forces on the diagram! Angle is not to scale!)

15. A **20 gm** sparrow flying at **5 m/s** toward a bird feeder mistakes the pane of glass for an opening and slams into it in **0.01 seconds**, stopping immediately. What is the **Force** exerted on the bird by the window pane?



16. Find the **Acceleration** of the **15 kg** wood block on the wood hardwood floor. Draw all the Forces on the block.



Part III: <u>Mass Confusion</u>

<u>Introduction</u>
In Part III, you are going to find the Mass of an object WITHOUT measuring it with an electronic balance, a triple-beam balance or a spring scale. Using only Newton's Laws of Motion and Friction concepts, the Mass of the Friction Block can be found. It is up to you and your partner to design an experiment to find the Mass of your Friction Block by ANY method of your choosing. You may **<u>NOT</u>** weigh the Friction Block with any electronic balance, a triple-beam balance or a spring scale.

<u>Materials:</u>
- Friction Block
- Newton PUSH scale
- Table of Coefficients of Friction

<u>Instructions and Procedures</u>
- As a team, design an experiment to determine the Mass of your block (in Kg).
- You may **<u>NOT</u>** weigh the Friction Block with any electronic balance, a triple-beam balance or a spring scale. If you are observed weighing the Friction Block, you will NOT receive credit for this part of the lab.
- Be certain to record the Friction Block # on the lab.

Your Friction Block Sample # ________________________
Your Friction Block Mass ________________________

<u>Lab Questions:</u>
17. Discuss and list the procedures your lab team used to determine the Mass of your Friction Block.

18. Draw a diagram of your experimental set-up.

19. After calculating the mass of your Friction Block, obtain the actual mass from your teacher and determine the % Error of the Friction Block's Mass.

$$\frac{\textbf{ACTUAL MASS} - \textbf{EXPERIMENTAL MASS}}{\textbf{ACTUAL MASS}} \textbf{ X 100 = \% ERROR}$$

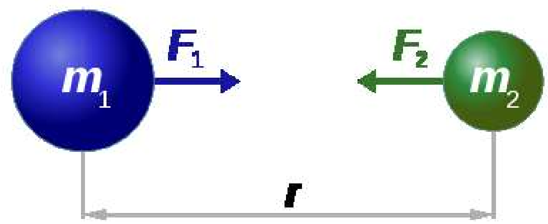
Part IV: <u>Newton's Universal Gravity Simulation</u>

<u>Introduction</u>

Universal Gravitation, as proposed by Sir Isaac Newton, is a concept by which all masses exhibit a gravitational attraction for all other masses based on certain fixed rules of the universe. Even though scientists do not yet understand the underlying nature of gravitational forces, we do observe certain fundamental relationships that occur between objects. The effects of Gravitational Attraction with changes in Mass and Gravitational Attraction with changes in Distance between objects can be tested with predictable results. In this lab, you and your partner will experiment with three simulations that illustrate the concepts that Newton proposed hundreds of years ago. Even though we cannot measure the minute changes in Gravitational Forces between objects in our lab, you will use simulations that will mimic gravity's influence on objects around us.

<u>Materials:</u>

- LASER pointer/Flashlight
- Diffraction grating set-up
- Laptop computer
- Metric ruler
- Calculator



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

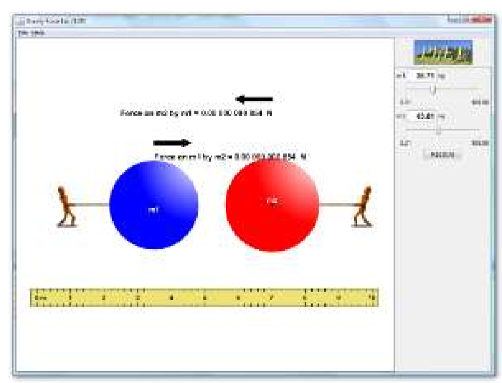
Section A: <u>Gravitational Forces Simulation</u>

<u>Instructions and Procedures:</u>

- Open the ***<u>Gravity Force Simulation</u>*** at the website…
  http://phet.colorado.edu/simulations/sims.php?sim=Gravity_Force_Lab

or

a. Type in "phET" into Google and click on "*PhET*: Free online physics…"
b. Once at the website, click on "Physics"
c. Scroll down to the "Gravity Force Lab" simulation.
d. Click "Run Now" and allow the simulation to run on your computer.



- With this simulation, you can experiment with the various factors that affect Gravitational Forces between two objects… **<u>Mass</u>** and **<u>Distance</u>**.
- A "movable" tape measure is present in the simulation to help you measure distances between the centers of the two masses. Remember that "r" is the distance between the CENTERS of the masses! Use this simulation to test the concepts about the factors that affect the Gravitational Forces between two objects.

- You can also “move” the masses to different spots on the screen and even change the magnitude of each individual mass up to 100kg.
- Using the simulation, answer the following questions by experimenting with the masses and the “movable” tape measure.

*** EACH TEAM MEMBER SHOULD WORK THROUGH THE SIMULATION!**

20. Set the two masses at **12 kg** each. **WITHOUT** using the tape measure, move the masses until the Gravitational Force between them is **6.0×10^{-10} N**. Using the Law of Universal Gravitational equation, **CALCULATE** what the **Distance between the Centers of the Masses (r)** SHOULD be.

Answer [ ]

$$F_g = \frac{G\, m_1 m_2}{r^2}$$

21. Without moving the masses, move the tape measure in position and record “**r**”.

Answer [ ]

22. Does your calculation agree with the measured distance?

Answer____

23. Using the initial Gravitational Force of **6.0×10^{-10} N** between the two masses, **double the distance** between the masses. What happens to the **Force (F_g)** between the masses now?

Initial Gravitational Force	**Gravitational Force (AFTER doubling the distance)**

Answer____

24. Using the initial Gravitational Force of **6.0×10^{-10} N** between the two masses, **halve the distance** between the masses. What happens to the **Force (F_g)** between the masses now?

Initial Gravitational Force	**Gravitational Force (AFTER doubling the distance)**

Answer ____

25. With the initial Gravitational Force set at **<u>6.0 X 10^{-10} N</u>** between the two masses, **<u>CHANGE</u>** the **<u>Mass of EACH object to 24 kg</u>.** Using the Law of Universal Gravitational equation, calculate what the $\mathbf{F_g}$ between the two Masses SHOULD be.

$$F_g = \frac{G\, m_1 m_2}{r^2}$$

Gravitational Force (AFTER doubling EACH mass)

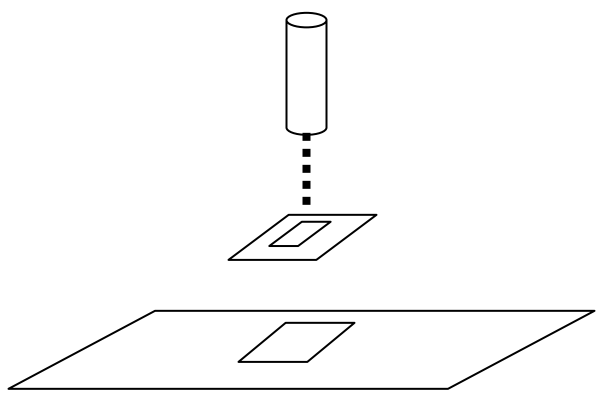
26. Does your new $\mathbf{F_g}$ calculation agree with the simulation?

Answer ____

Section B: <u>Universal Gravitation using a LASER Model</u>

<u>Instructions and Procedures:</u>

You are now going to experiment with the penlight LASER to confirm the concept of the **<u>Inverse Square Law of Universal Gravitation</u>**. The Strength of Magnetic Fields, Electrostatic Forces and Light Intensity ALSO exhibit an inverse square law in the physics universe. Since we cannot "see" the yet discovered graviton particles, which are the proposed force carriers of gravity, the LASER/Diffraction grating set-up will be substituted as the graviton particle source, as shown below.



- Using the 4cm x 4cm square on the paper, you and your partner position the diffraction grating with the LASER so that you get **<u>25 dots</u>** inside the square. The "dots" will represent the Graviton particles produced by an object possessing mass.
- Record the distance (in cm) of your diffraction grating FROM THE PAPER in the **<u>Data Table # 4</u>** below. This will be "**r.**"
- Now move the diffraction grating FROM THE PAPER a distance of **2r**. Record the number of dots inside the square. Continue to ADD an **<u>additional</u>** "**r**" for each trial and record the number of dots inside the square.

Data Table # 4

Dots (Graviton Particles)	**Distance (cm)**
25	**r =**
	2r =
	3r =
	4r =
	5r =

27. Create a graph of **Dots (Graviton Particles) vs. Distance**. Be certain to **TITLE** and **LABEL** your graph. Select a trend line and include an **equation** on your graph!

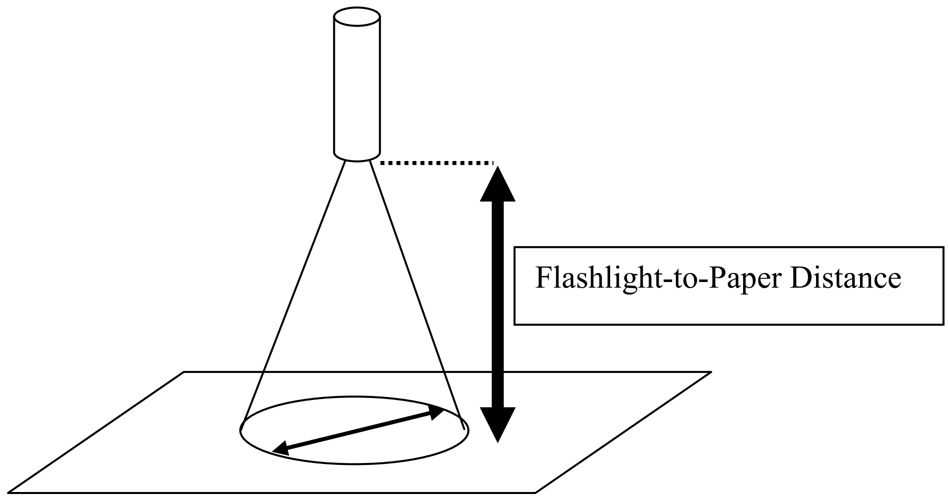
28. What is the equation of your graph?

29. Does the **equation** from YOUR graph reflect the **Inverse Square Law for Gravitational Forces**? Explain.

Section C: Universal Gravitation using a FLASHLIGHT Model

Instructions and Procedures

- Using the Flashlight button on your LASER pen, shine the flashlight onto this lab paper with a "Flashlight-to-Paper Distance" of **1 cm**.
- Have your partner mark the diameter on this lab paper of the **distinct** white circle formed by the flashlight beneath the "1 cm distance" on the lab paper. (See diagram below.)
- Increase the of the "Flashlight-to-Paper Distance" to **2 cm** and repeat the process for 3, 4 and 5 cm distances.
- Continue to mark the diameter of each **distinct** white circle at the specified distance on the lab paper. **BE PRECISE WITH YOUR MEASUREMENTS!**



<u>Flashlight-to-Paper Distance Drawings</u>

<u>1 cm distance</u> **<u>2 cm distance</u>** **<u>3 cm distance</u>** **<u>4 cm distance</u>** **<u>5 cm distance</u>**

- Using **Area=πr^2**, find the **<u>Area of each circle</u>**.

Area-1	Area-2	Area-3	Area-4	Area-5

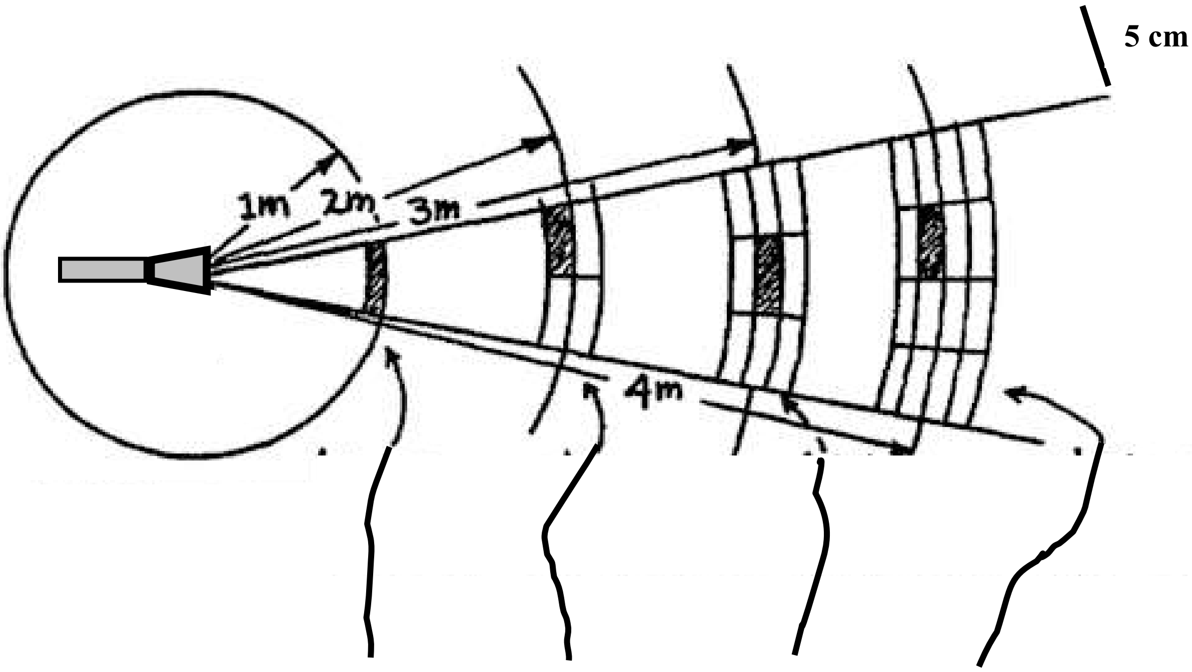
<u>Lab Questions:</u>

- Gravitational Forces vs. Distance exhibit the **<u>SAME</u>** relationship as the Intensity of Light vs. Distance. The diagram below illustrates Light Intensity vs. Distance modeling how gravity diminishes as changes in distance from the source increase. Using the Flashlight Model and your Light Area calculations as a guide to answer Questions 31a and 31b.

- Complete **<u>Data Table #5</u>** below which models Gravitational Force-Distance relationships.

- **<u>Sketch a diagram</u>** for the “Area Units” for a **<u>5 cm</u>** distance.

Light Intensity Model for Gravitational Force vs. Distance



Data Table #5

Area Units (# of "squares")	<u>Area Unit</u> 1	<u>Area Unit</u> 4	<u>Area Unit</u>	<u>Area Unit</u>	<u>Area Unit</u>
Light Intensity (Gravitational Force) F_g is "How many X's as great?"	<u>Intensity Unit</u> 1	<u>Intensity Unit</u>	<u>Intensity Unit</u>	<u>Intensity Unit</u>	<u>Intensity Unit</u>

30. Did YOUR calculated flashlight circle areas closely agree with the Inverse Square Law? (Did the Area relationships increase exponentially?)

31. Did YOUR graph of <u>Dots vs. Distance</u> closely agree with the Inverse Square Law? (Did the Dots vs. Distance relationship increase exponentially?)

32. Can a planet or star's gravitational forces ever become **<u>zero</u>** anywhere in the universe?

33. Force F is exerted by Mass #1 on Mass #2 and they are at a distance r from their centers. If Mass #1 is tripled, Mass #2 is quartered and distance r is doubled, what is the Force that Mass #2 exerts on Mass #1 in terms of F?

34a. If our *Sun* suddenly became a "Black Hole", what would happen to the Earth?

a. The Earth would fly tangent to its orbit into space.
b. The Earth would be pulled into the Black Hole by the massive increase in the gravity field.
c. The Earth would be destroyed due to the increased Force of Gravity.
d. The Earth would continue in its usual orbit.

34b. Using the concept of $\mathbf{F_g = \frac{G\, m_1 m_2}{r^2}}$, explain your answer to Question #34a.

You may need to research what a Black Hole is!