Experiment 8

Gravity (Friday edit)

Equipment

Pair of magnets	Ruler
Magnetic force apparatus- (tube with slit attached to wood base)	Triple beam balance
	Mass set
	Calipers

INTRODUCTION

Sir Issac Newton did not discover gravity. What Newton 'discovered' was that ***gravity is universal***-that it is not unique to earth, as others of his time assumed.

The ancients believed that the stars, planets and the Moon move in devine circles which were free from any "impelling forces". Newton recognized that a force of some kind must act on the planets and that this *force must be directed towards a fixed central point* – the sun.

Newton's intuition *(a single set of laws for earth and the the heavens)* was a **universal law of gravity** which states that everything pulls on every thing else in a way that involves only mass and distance. This can be expressed symbolically as

$$Force \sim \frac{mass_1 \times mass_2}{\text{distance}^2} \text{ or } F = G\frac{m_1 \times m_2}{\text{d}^2}$$

where m_1 and m_2 are the masses of the two bodies and d is the **distance between their centers.** G is the *universal gravitational constant* with an experimentally determined value of $6.67 \times 10^{-11} N \cdot m^2 / kg^2$.

The value of G indicates that gravity is a very weak force-the weakest of presently known four fundamental forces.

Gravity and distance are related by what is known as the **inverse square law** where the *effect of a localized source spreads uniformly throughout the surrounding space.*

When you step on a bathroom scale you compress a spring. When the pointer stops, you and the scale (i.e., the spring) are in static equilibrium. If you stand on a scale while in an elevator you will find that your weight varies as the elevator accelerates up or down. If the cable breaks and the elevator falls freely, your weight (according to the spring scale reading) will be zero. **Are you weightless?**

To answer this question we must first define what we mean by weight. A 'broad' definition of weight is the *force exerted by the object "against a supporting force or a weighing scale"*. **According to this definition you are as heavy as you feel.** You would thus be weightless in a freely falling elevator (even though there is still a gravitational force acting on you).

The earth and the moon pull on each other (even though they do not touch) through a mechanism called *action at a distance.* We can regard the moon as interacting with the gravitational field of the earth. The properties of the space surrounding any massive body can considered to be altered in such a way that another body with mass in this region experiences a force. *This is explained by Einstein's theory of general relativity.*

A gravitational field is an example of a force field. Other examples are the electric and the magnetic fields.

Projectile Motion-Without gravity, you could toss a rock at an angle skyward and it would follow a straight-line path. Because of gravity, however, the path curves. See figures 10.6, 10.7 and 10.8 of text. *A tossed object (e.g., a ball, rock or cannonball) that is projected by some means and continues in motion by its own inertia is called a projectile.*

Part A The weight and mass of you and your cell phone

Students are commonly confused about the difference between mass and weight and the proper units of each. Part of the confusion stems from the fact that in the United States the *quantity of matter* is commonly described by its weight (with common units of *pound force* or lb_f) and in most of the world the *quantity of matter* is described by its mass with units of kg. The units of force in the SI system is the newton. **Please note that henceforth, "pounds" refers to "pound force".**

In this exercise you will: 1) convert your weight in pounds from a **bathroom scale** and convert to both mass and weight in SI units, 2) measure your cell phone's mass on a **balance** and convert to its weight in SI units. An example follows.

Weight on bathroom scale = 165 pounds

Convert to mass in SI units-

165 pounds x $\dfrac{1\ kg}{2.205 \text{ pounds}}$ = 74.8 kg

Convert to to (SI)weight

Weight = 74.8 kg x $\dfrac{9.80\ N}{1 \text{ kg}}$ = 733.3 N

Mass of cell phone = 108.28 g
= 0.10828 kg

Convert to weight in SI units

0.10828 kg x $\dfrac{9.80\ N}{1 \text{ kg}}$ = 1.06 N

Weight of cell phone = 1.06 N

Repeat the calculations above in the data section using your weight and the mass of your cell phone. If you do not have a cell phone use a mass of 100g. *If you have qualms about revealing your weight, use the weight that you would like to weigh.*

Part B- The look of gravity (in a uniform gravitational field e.g., surface of earth).

Gravity's Rainbow is a postmodern novel written by Thomas Pynchon and first published in 1973 was a winner of the national book award. The novel's title is a reference to the parabolic trajectory of a (World War 2) V-2 rocket as it moves under the influence of (only) gravity after its engine stops firing (air resistance notwithstanding).

While the fact that projectiles move in parabolic paths is known by all physicists and some writers, Hollywood moviemakers seem to be totally ignorant of this fact as well as the laws of the conservation of momentum, conservation of energy and Newton's Third law (of action-reaction).

In this section of the experiment projectile motion and how it really looks is examined with particular focus on a Hollywood movie or two. See figure 10.38 below.

Procedure

You will estimate the actual path of a projectile using very simple math and the basic knowledge of how a projectile actually behaves. The steps are as follows:

1. **On figures 2 & b below**, draw a straight line extending from (and parallel to) the barrel of the ballistic pendulum to the vertical meter stick (also see Figure 10.8 on page 51 below).

2. Using the time of flight given and the equation $\text{distance} = \frac{1}{2}gt^2$ or $\text{distance} = 5t^2$, **determine the distance** the projectile should fall.

3. **Indicate this distance** on the vertical meter stick

4. Draw a parabolic path that **intersects the ruler** at the bottom of the vertical line that you calculated above in step 2 (and drew in step 3 above).

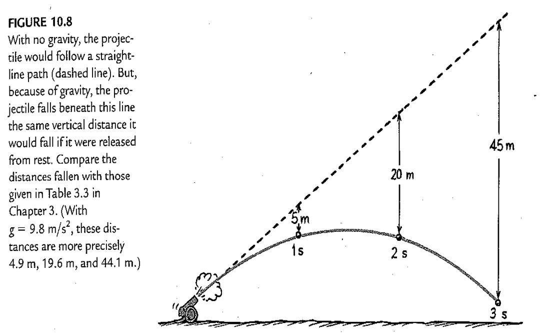


Figure 10.8 from Hewitt textbook

Movie Scene analysis.

5 Your TA will show a clip (or clips) from a movie featuring projectile motion and you will analyze and discuss. See page 50 below for how to do. **You will show this work on figures on page 54.**

Part C- The feel of gravity-

The inverse-square law

(Or why black holes 'suck' so hard)

The force of gravity obeys the inverse square law. **Magnetic force obeys a different relationship, that effectively looks like an inverse square law**. Because gravity is so weak we will use magnets to examine the behavior of the force (i.e., 'the feel') of gravity.

Although gravity and magnets obey different force laws, they are similar enough to explain **why a pair of strong magnets will forcefully pinch your finger if you are not careful** and why a black hole has a gravitational attraction that can be so intense that even light cannot escape. See figure five below.

Procedure

1. Record the mass of the weight platform and the aluminum rod on your table. See figure 6 below. Put mass values in data table.

2. Measure the distance between the top on the lower magnet and the bottom of the top magnet. Initially the magnets will be slightly tilted. They will straighten up when more mass is placed on them. See figure 6 below. Put this starting distance in the first row of data table 1.

3. Place the alumium rod inside the tube on top of the magnets and remeasure the the distance. Record mass and new distance in table 1.

4. Remove the rod and replace with the weight holder apparatus. Record mass and new distance of the magnets in table 1.

5. Add mass (place them upside down) to the weight holder until the magnets almost touch. Record all masses and distances in table 1.

6. Plot total mass vs. distance using Graphical Analysis software**. Duplicate plot on data page 53 below.**

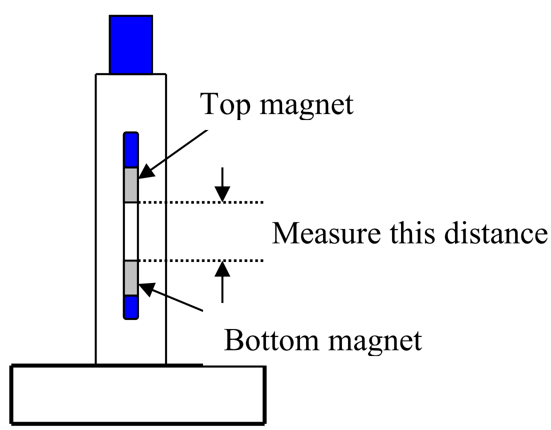
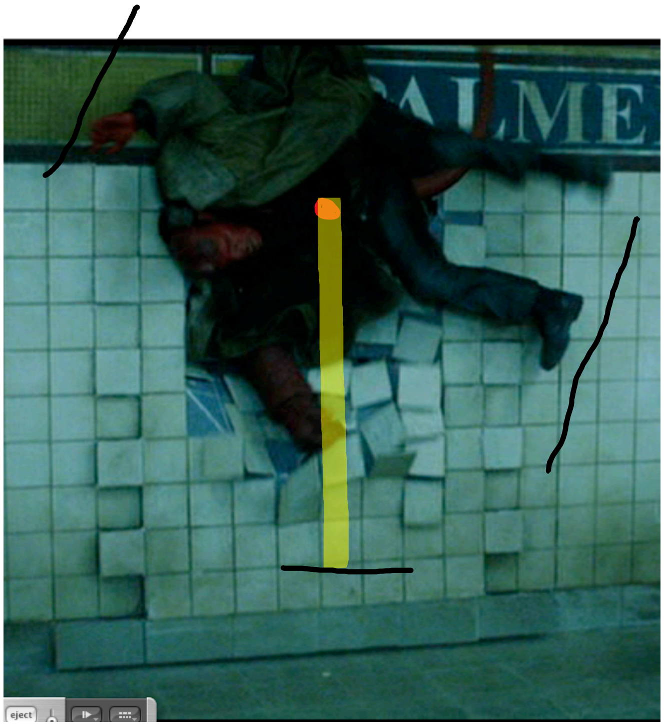


Figure 6

How to complete Hellboy video



Hopefully after viewing the video clips you all see how unrealistic both clips were!

Although Hellboy spent (an easily measurable time) in the air, he did not start to fall until he hit the wall & glass, respectively. In other words, he should have started falling immediately after he was thrown.

The purpose of this part of lab is to show how far Hellboy would have fallen in the presence of gravity *(based upon the times you measured).*

This is what to do.

1) Draw two lines to (approximately) represent Hellboy's height – 2 meters (~6 foot 7 inches). See black lines on left hand diagram above. ***Do for both diagrams.***

2) Draw a dot to represent his center of mass (see red dot on left hand figure above).

3) Using distance = 5* $(\text{time})^2$ calculate how far Hellboy should have fallen (in both photos based upon your own times).

4) You have a scale since you know Hellboy is 2 meters tall. You can then show how far he should have fallen in a given time.

5) For example, if you had measured ½ seconds (you will measure more time than this), we see that

   distance = 5 * $(1/2)^2$ = 5/4 = 1.25 meters.

   This distance (the length of the yellow line) is approximately 2/3 of Hellboy's height of 2 meters (i.e., 2/3 the length of the two black lines).

The distance (1.25 m) that Hellboy falls (during the measured time of ½ seconds) is shown above in yellow.

6) Use the same procedure for the small figure of Hellboy using the time you measured the video.

Data

Show all work for **Part A** here.

Mass vs. Distance plot

Your weight (SI units) = ____________

Mass of cell phone = _____________

Weight of cell phone = ___________

The Feel of Gravity Data Table

mass of magnet (g)	mass of what is on top of magnet (g)	Total mass (grams) [sum of columns 1 & 2]	distance (cm)
12	magnet only 0	12	
12	short rod 38g		
12	long rod		
12	mass platform only		
12	mass platform+500g		
12	mass platform+1000g		
12	mass platform+1500g		
12	mass platform+2000g		
12	mass platform+2500g		
12	mass platform+3000g		
12	mass platform+3500g		

Note to simplify question 4. Look at data table above and use a distance that is close to the measured thickness skin between your thumb & index finger. Use the mass associated with the distance as the pinch force. You may have to use an estimate if distances are slightly different.

The Look of Gravity

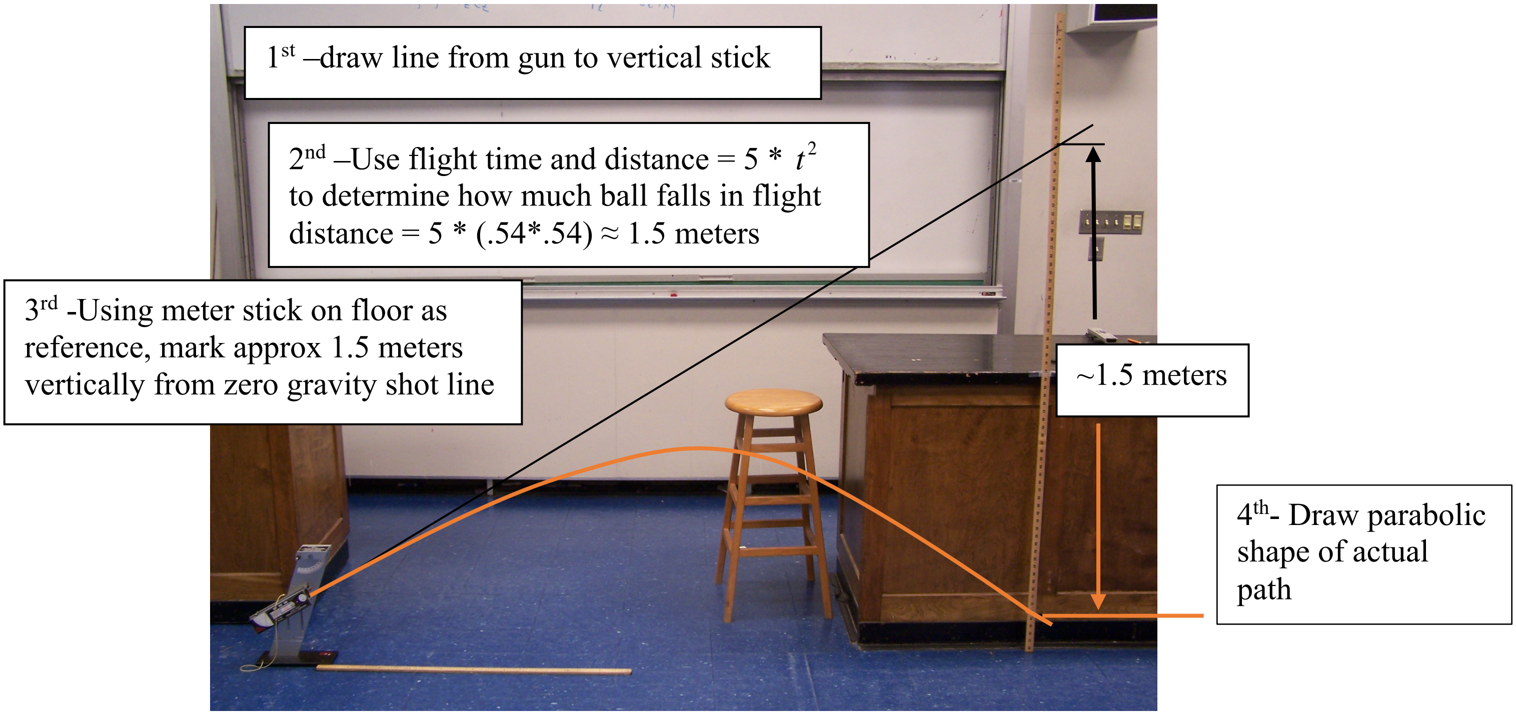


Figure 1- Time of flight to vertical (2 meter) stick = 0.54 seconds

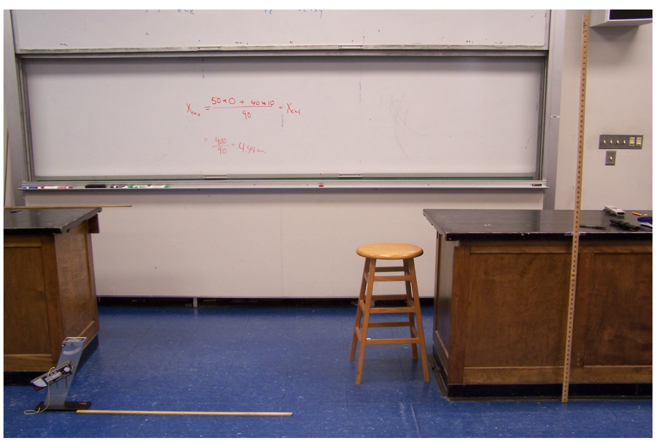


Figure 2- Time of flight to vertical (2 meter) stick = 0.40 seconds

Figure 3- Time of flight to vertical (2 meter) stick = 0.70 seconds

Movie Stills from the Hellboy (Show all work)
(Assume Hellboy is 2 meters tall)

Questions

1. If you took a bathroom scale into an elevator would you weigh more or less when it accelerated up? What about when it accelerated down? Explain your answer.

2. The elevators in the Landmark Tower, in Yokohama, Japan, are among the fastest in the world. They accelerate upward at 3.125 m/s^2 for 4.00s to reach their final speed. Assuming they accelerate downward at the same rate and using the relationship given below answer the following. Show work.

$$Weight_{moving} = Weight_{stationary} \pm \frac{3.125 m/s^2}{9.80 m/s^2} Weight_{stationary}$$

Your maximum weight in elevator = ____________lbs
Your minimum weight in elevator = ____________lbs

3. Did your Plots look like an inverse square law plot? Why or why not.

4. Using a caliper, measure the thickness of the skin between you thumb and index finger Using this value and your plot estimate how much force a pair of the magnets in lab would exert on you skin if they were to pinch you. This is done by locating the measured skin thickness on the x-axis and **drawing a vertical line** that intersects your curve and then extending **(drawing) a horizontal line** to the y-axis which gives you the amount of pinch force.

Pinch force = _______N

5. The sun has a diameter of approximately 870,000 miles. By how much would its gravity at its surface increase it were to shrink down (while maintaining its mass) to *approximately the size of the earth* say to 8700 miles. (Since it's a gaseous body it really does not have a surface). Show work. Remember gravity is an inverse square force law.