

Experiment 8

Gravity

Equipment

Pair of magnets	Bathroom scales
Magnetic force apparatus- (tube with slit attached to wood base)	Ruler
	Digital 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 divine 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 revolutionary idea and is manifested in his law **universal 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

$$\text{Force} \sim \frac{\text{mass}_1 \times \text{mass}_2}{\text{distance}^2} \text{ or } F = G \frac{m_1 \times m_2}{d^2}$$

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 $6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2$.

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 be considered to altered in such a way that another body with mass in this region experiences a force.

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 straightline 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.*

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) measure your weight in pounds on 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-

$$165 \text{ pounds} \times \frac{1 \text{ kg}}{2.205 \text{ pounds}} = 74.8 \text{ kg}$$

Convert to (SI) weight

$$\text{Weight} = 74.8 \text{ kg} \times \frac{9.80 \text{ N}}{1 \text{ kg}} = 733.3 \text{ N}$$

Mass of cell phone = 108.28 g
= 0.10828 kg

Convert to weight in SI units

$$0.10828 \text{ kg} \times \frac{9.80 \text{ N}}{1 \text{ kg}} = 1.06 \text{ N}$$

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.*

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.

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.

First –You 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:

- **Draw a straight line** extending from (and parallel to) the barrel of the ballistic pendulum to the vertical meter stick (see Figure 10.8 from text below).

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

-**Indicate this distance** on the vertical meter stick

Second – You will use the knowledge above to make predictions about a real projectile on figures two and three below. Your TA will then show you a video of a real ball being projected to examine how your predictions compared to experiment.

Third - Your TA will show a clip (or clips) from a movie featuring projectile motion and you will analyze and discuss.

**The feel of gravity-
The inverse-square law**
(Why black holes 'suck' so hard)

The force of gravity obeys the inverse square law while **magnetic force** effectively obey what is called **the inverse cube 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. Measure the mass of the weight platform and the aluminum rod on your table. See figure 6 below. Put mass values in data table 1 and convert to force.

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

3. Place the short aluminum rod inside the tube on top of the magnets and remeasure the the distance. Record mass and new distance in table 1. Remove short. Repeat for longer rod.

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 to the weight holder until the magnets almost touch. Record all masses and distances in table 1.

6. Plot force vs. distance using **Graphical Analysis** software. Curve fit

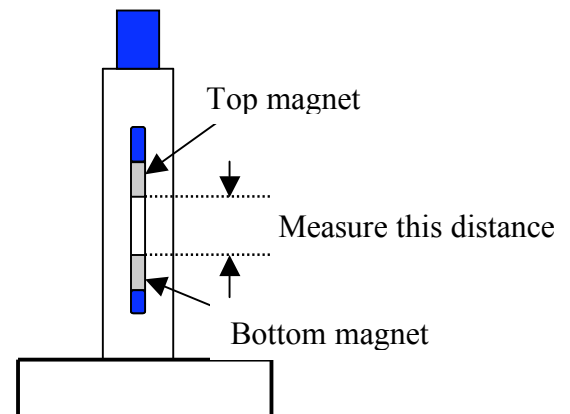


Figure 6

Data

Weight on bathroom scale = _____

Show all calculations below

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]	Total mass (kg)	Force (use $g = 10 \text{ m/s/s}$) (N)	distance (cm)
12	magnet only	12	0.012 kg	.12	
12	short rod				
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				

The Look of Gravity

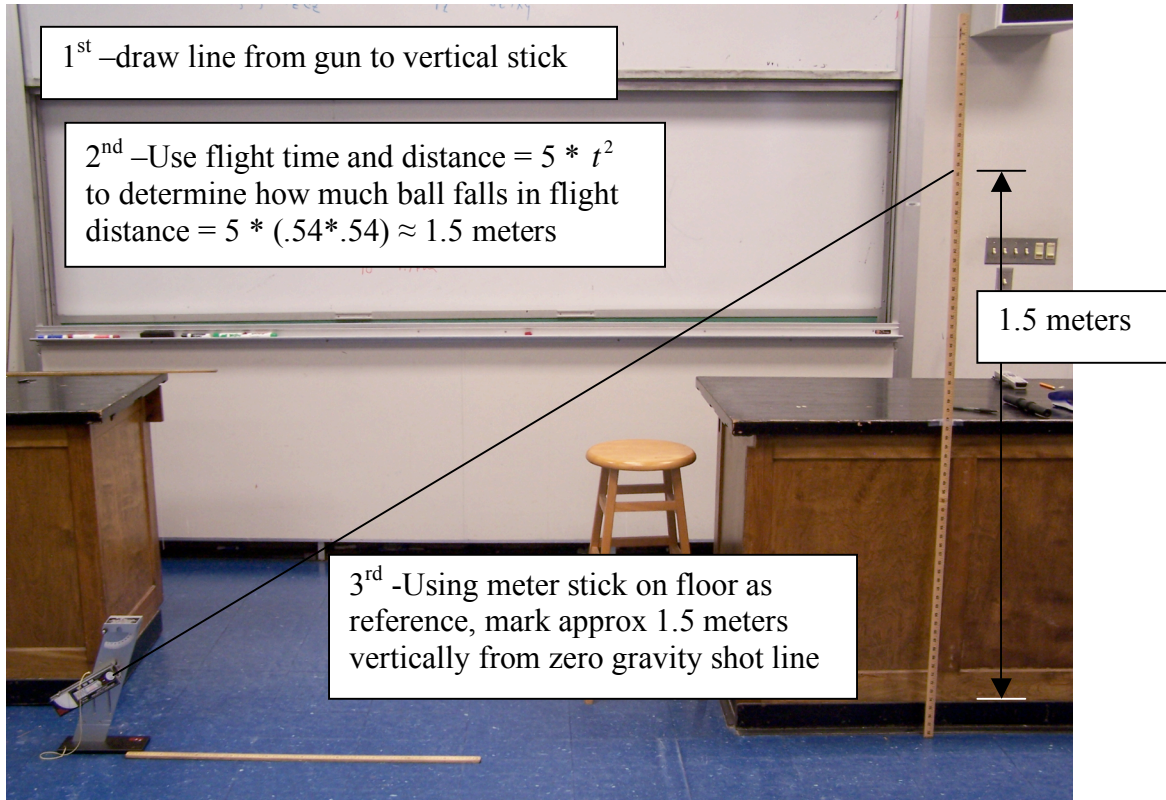


Figure 1- Time of flight to vertical (2 meter) stick = 0.54 seconds



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



Figure 4- Photo from the movie **Speed**

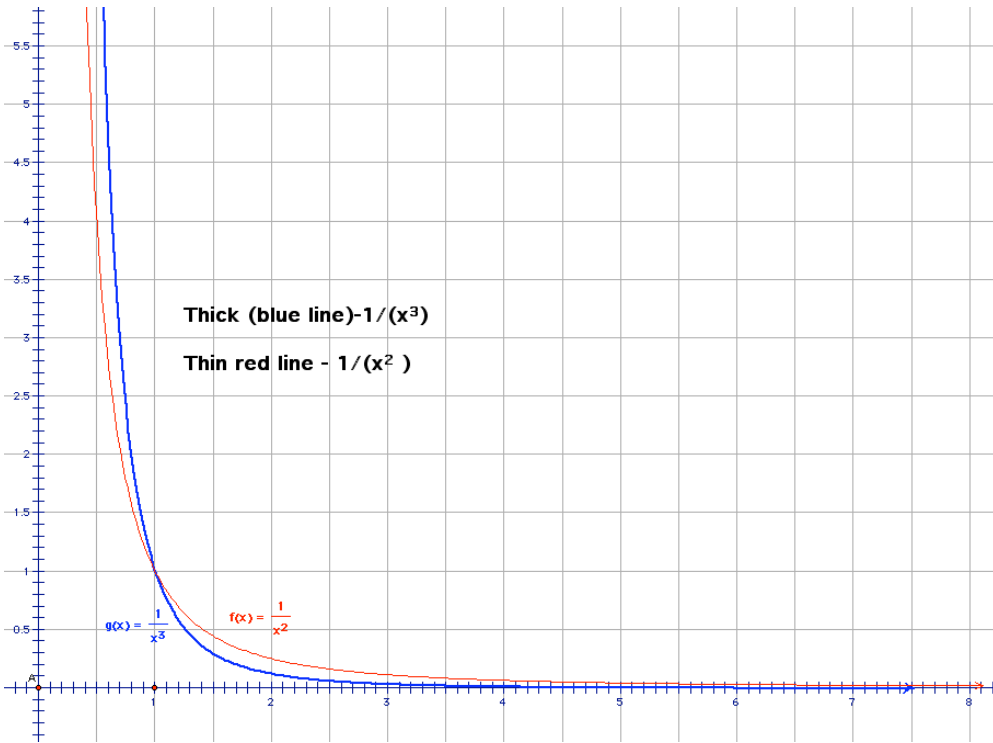


Figure 5- Plot of $y = \frac{1}{x^2}$ and $y = \frac{1}{x^3}$

FIGURE 10.8

With no gravity, the projectile would follow a straight-line path (dashed line). But, because of gravity, the projectile falls beneath this line the same vertical distance it would fall if it were released from rest. Compare the distances fallen with those given in Table 3.3 in Chapter 3. (With $g = 9.8 \text{ m/s}^2$, these distances are more precisely 4.9 m, 19.6 m, and 44.1 m.)

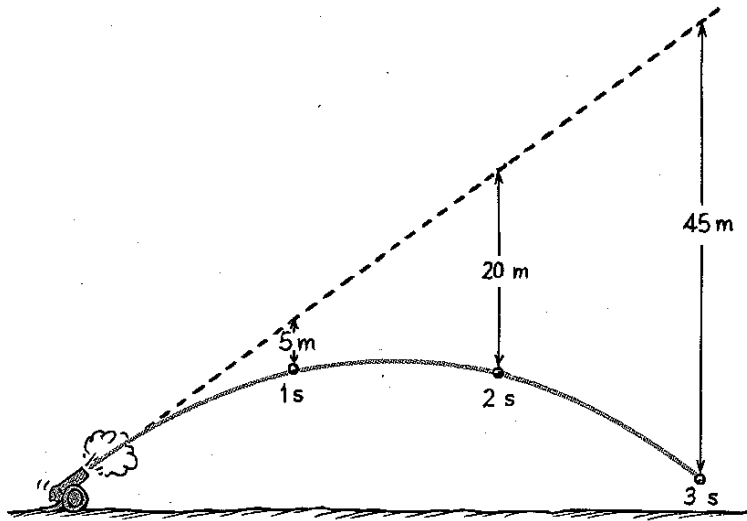


Figure 10.8 from Hewitt textbook

Questions

The first group to finish the experiment will take a bathroom scale into the elevator in Lewis hall and perform the following experiment. Each member of the group will stand on a scale and go **down to the first floor** and they will record the maximum increase or decrease in weight. Once they get to the basement level (bottom floor), they will then go **back up to the 2nd floor**. They will again record their maximum or minimum weight. For completeness they should repeat experiment once more. The following data will be used by the whole lab.

Lab Partner 1- **Starting wt** _____ **lbs** **Minimum wt** _____ **lbs** **Maximum wt** _____ **lbs**

Lab Partner 2- **Starting weight** _____ **lbs** **Minimum weight** _____ **lbs** **Maximum weight** _____ **lbs**

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.

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

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. How much would its gravity at its surface increase if it were to shrink down 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.