



## PROJECTILE MOTION AND NEWTON'S LAWS

*BY,*  
**SANDRA GREEEN**  
**ANTHONY JAMES**  
**ALBERT POLLARD**

## **Introduction**

In the 17<sup>th</sup> century Galileo Galilei theorized that the force or “impetus” of a throw must overcome gravity in order for the object to lift off the ground and displaced. He later explained that projectile motion could be divided into two independent motions – uniform horizontal motion and vertical accelerated motion due to gravity. Later on Sir Isaac Newton added to this theory in his universal theory of mechanics. While Galilei believed that the impetus or force of the object was a product of the nature of the object, Newton deduced that objects needed an **external** force to change motion, not to sustain constant motion.

If a ball is dropped from a certain height, and another one is simultaneously projected horizontally from the same height, which one will strike the ground first? Ask the average student this question and chances are the answer you will get is that the one which is dropped will hit the ground first. Usually the reasoning is that the other ball has a longer distance to travel because it was subject to more “force.” Another common misconception is that objects which are not in motion are not subject to gravitational forces.

The objective of this project is to show the students that regardless of how far a ball is thrown horizontally, if another ball is dropped from the same height, both balls will strike the ground at the same time. At the same time students must be made aware of the fact that objects which are not in motion are also subject to the force of gravity. This project is about constructing a device to prove these concepts.

## **Background**

Many projectiles undergo a vertical and a horizontal motion. As the projectile moves upward and/or downward it is also moving horizontally. However, the horizontal component of motion is completely independent of the vertical component of motion. Each component is independent of the other. In projectile motion the two following important factors are noted:

- (1) The object's horizontal component of motion remains constant, because no horizontal component force is acting on it. Gravity acts only downwards, so the only acceleration of the object is downward.
- (2) Both the free-falling object and the projected object fall the same vertical distance in the same time since the “pull” of gravity accelerates the object at 9.8 m/sec.

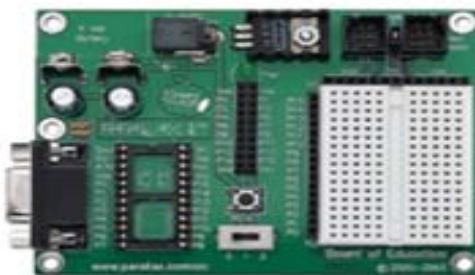
## **Project**

The project consisted of these main components:

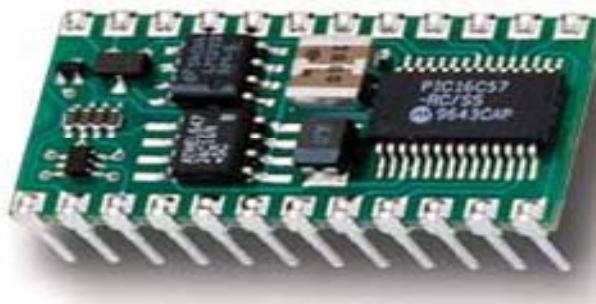
- **Equipment list.** This would include all the **sensors** and **actuators** involved in the project. The circuitry will be built on BASIC Stamp and a breadboard. In the latter part of the project the circuitry will be detached from BASIC Stamp and transferred to a 15-pin connector.
- The **schematic** for the circuit
- **Written program** in BASIC Stamp Editor
- A **device** which allowed two balls to be released from a platform simultaneously. One would be released from a trap door (free fall) and the other would be projected simultaneously.
- A **brief explanation** of how the device works.

## **Equipment list**

**The Board of Education, Revision C (28150)** is an electronic platform designed to work mainly in conjunction with the Basic Stamp 2 (BS2) microcontroller. The built-in breadboard houses sockets, which allows the user to perform a variety of applications. The project was first built on this board and then later transferred to a 15-pin connector.



**Basic Stamp – BS2ASIC.** The Stamp microcontroller is a single-board computer that runs the Parallax PBASIC language interpreter in its microcontroller. It is usually used in conjunction with the Board of Education platform.



**Breadboard.** This is a board with tiny sockets arranged on a grid. The two horizontal rows on the top and bottom are electrically linked to each other and are known as the positive and ground respectively. The holes in the middle columns are electrically linked by fives



**Lever Switch.** This is a mechanical switch that produces a very rapid transfer of contacts from one position to another. When the switch is closed, it allows current to flow through the circuit. Four lever switches were used in this project.



**Push Solenoid.** This is an electromagnet device consisting of a solenoid (usually a cylindrical coil of insulated wire wound in the form of a helix), in which an iron core is placed. When current passes through the coil, it induces a strong magnetic field which pushes the plunger forward.



**Pull Solenoid.** This is an electromagnet device consisting of a coil of wire called a solenoid and an iron plunger inserted partially inside the solenoid. When current flows through the solenoid, it produces a magnetic field just as a bar magnet. This magnetic field pulls then plunger. The strength of the solenoid's magnetic field is dependent upon the amount of current flowing through it.



**Resistor.** This is an electronic component that resists the flow of direct or alternating electric current. Resistors can limit or divide the current, reduce the voltage, protect an electric circuit, or provide large amounts of heat or light. Eight resistors were used in this project.



**Transistor.** This is a semiconductor device that acts as an electrical control switch and a current amplifier. Two npn bipolar junction transistors (BJT) are used in this project.



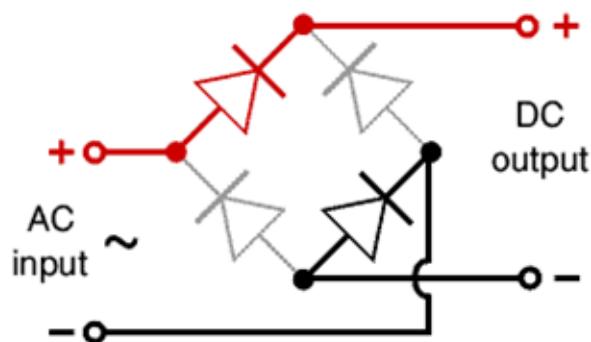
**Light Emitting Diode.** This is a semiconductor that emits light in the form of electroluminescence as current flows from the anode to the cathode. Two LEDs were used in this project.



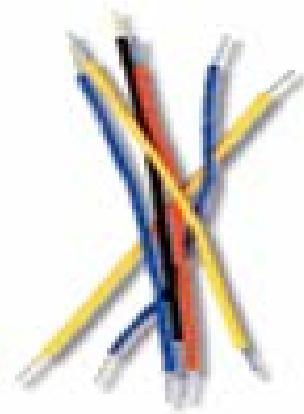
**Pushbutton Switch.** This is a mechanical switch which consists of a plunger-like component which makes or breaks circuit connections.



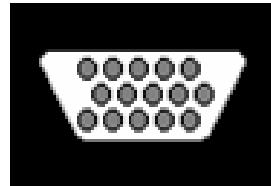
**Bridge Rectifier.** This is a special 4-diode package used to convert alternating current (AC) to direct current (DC) – a process called rectification. This was used to stabilize the current in this project.



**22-gauge Jumper Wires.** These color-coded wires were used to make electrical connections: black represented ground, red represented positive and white represented connections between components



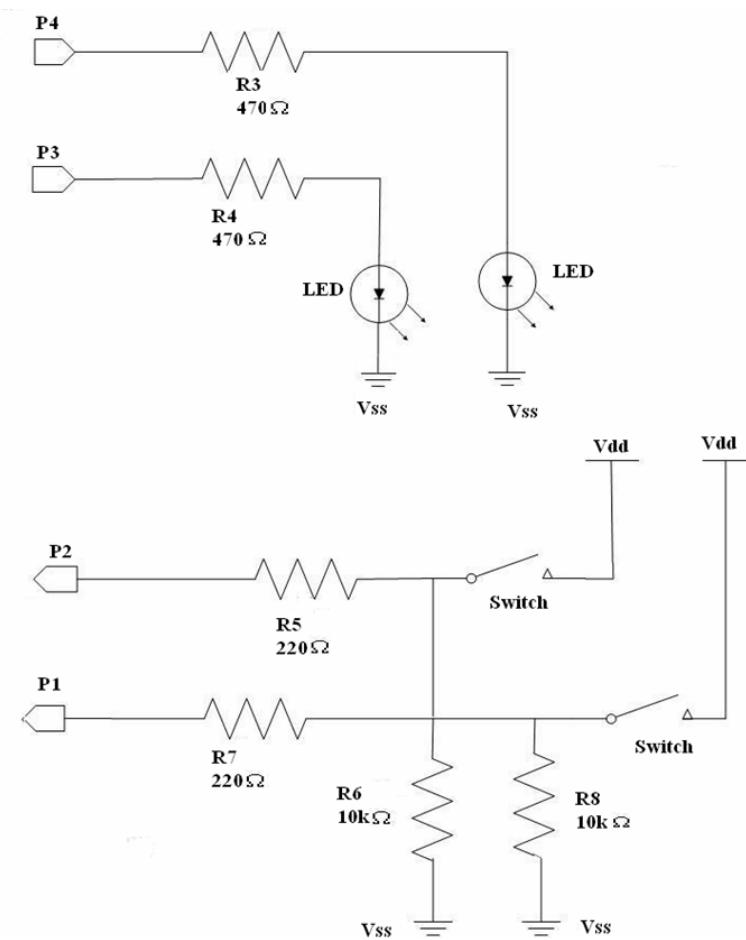
**Fifteen pin connector.** The connector wires were transferred from the BASIC Stamp to a fifteen pin connector. This was a more economical than using the BASIC Stamp board. Pins 6 – 13 were not used in this project.

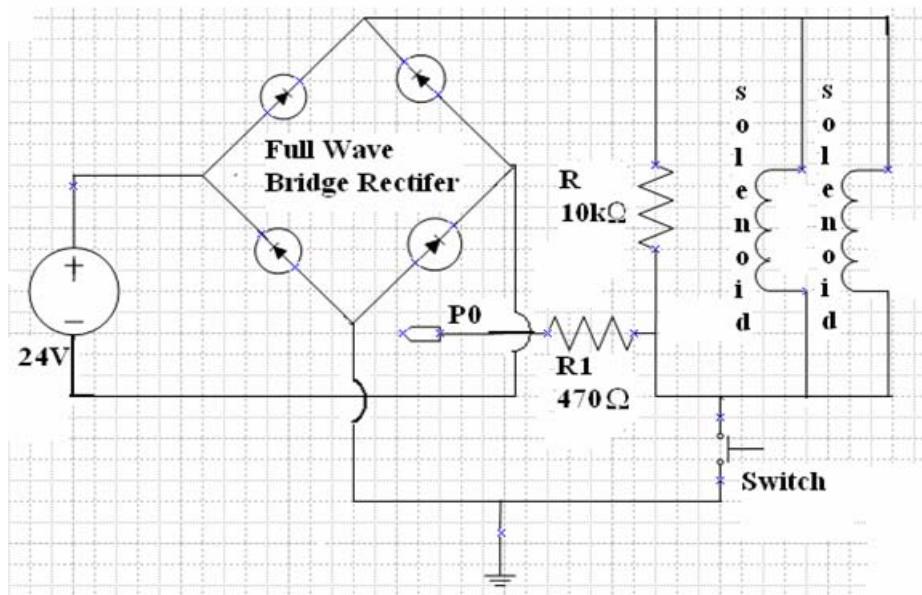


**AC/DC Adapter.** This is a power supply that converts alternating current (AC) into regulated DC voltages. A 24V 3.5A adapter was used in this project.

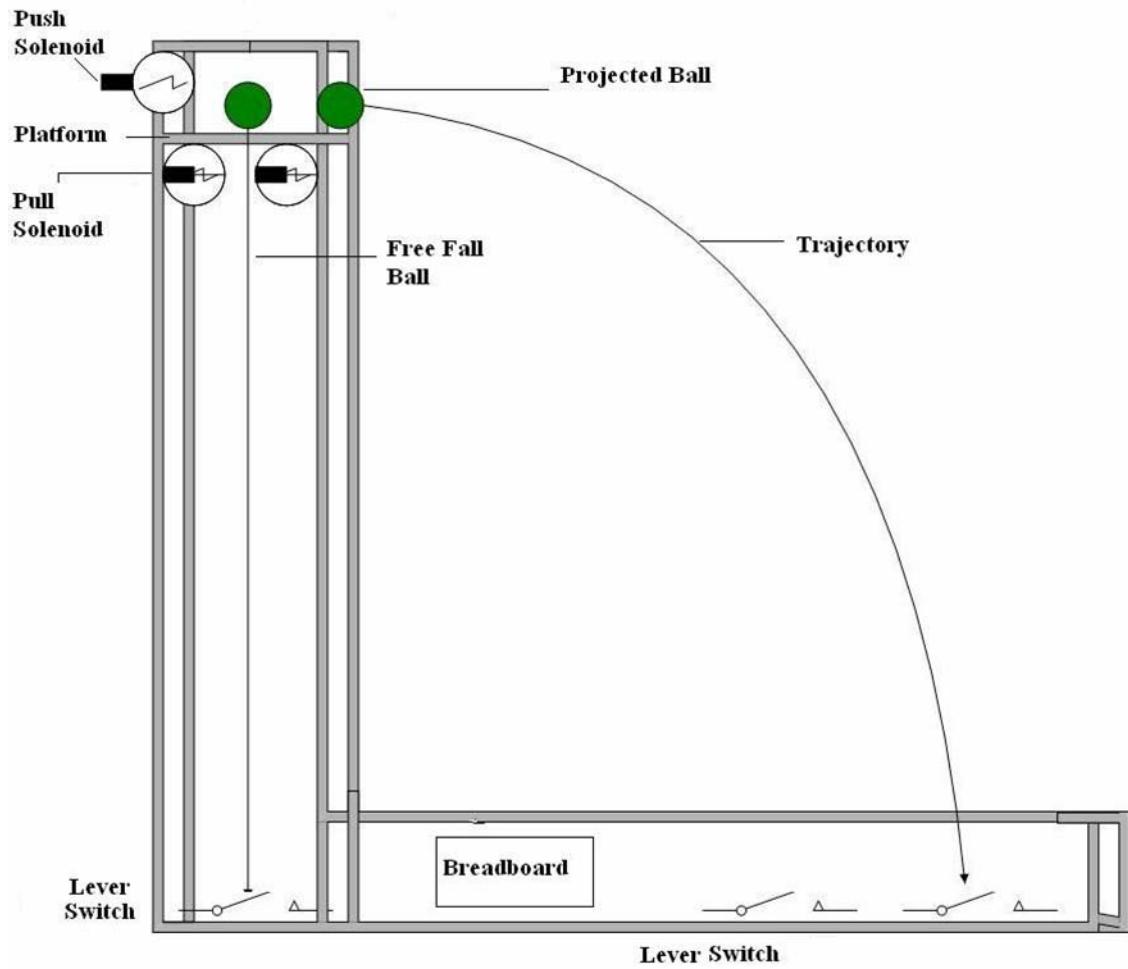


### Schematics





## The device



## **Program Code**

```
' {$STAMP BS2}
' {$PBASIC 2.5}
timeCounter VAR Word
counterA VAR Word
counterB VAR Word
DetectA VAR Bit
DetectB VAR Bit
stopA VAR Bit
STOPB VAR Bit
timeCounter=0
counterA=0
counterB=0
DetectA = IN3
DetectB = IN4
Main:
DO
DEBUG HOME
IF (IN0=0) THEN
GOSUB Counter
ENDIF
'GOSUB Display
LOOP

Display:
DEBUG HOME
'DEBUG ? IN0
'DEBUG ? IN1
'DEBUG ? IN2
'DEBUG ? stopA
'DEBUG ? stopB
DEBUG "a",DEC2 counterA/10,".", DEC1 counterA//10,"s",CR,CR
DEBUG "b",DEC2 counterB/10,".", DEC1 counterB//10,"s",CR, CR
LOW 3
LOW 4
RETURN
Counter:
DO
IF (stopA =1) & (stopB=1) THEN
    EXIT
ELSE
    PAUSE 96 'compensate the delay of running code: Reduce the pause time to 96ms but the
    "real" unit time is 100ms
    timeCounter = timeCounter+1
```

```
IF (IN1=1) & (IN2=1) THEN
stopA=IN3
STOPB=IN4
counterA=timeCounter
counterB=timeCounter
HIGH 3
HIGH 4
GOSUB Display
```

```
ELSEIF (IN1 = 1) THEN
stopA=IN1
counterA=timeCounter
HIGH 3
GOSUB Display
```

```
ELSEIF (IN2 = 1) THEN
STOPB=IN2
counterB=timeCounter
HIGH 4
GOSUB Display
ENDIF
ENDIF
LOOP
```

### **How the Device Works**

The push button is pressed. This triggers several things simultaneously – the solenoids release the balls so that one is dropped and the other is projected horizontally. At the same time the program triggers a timer which starts timing the process in milliseconds. The landing of the balls triggers the lever switches. This causes the LED's to light up and the time the balls took to get from the platform to the landing is recorded on the computer screen.

### **Problems Associated with Building the Project**

- Choosing the right push solenoid: This was a task because we had no prior knowledge of the “force” of the solenoid. Instead we were forced to use a table to determine the safe range of current (I) which could be used with the solenoid. With the help of our mentor Keith, we were finally able to find a 24-V converter which allowed the solenoid to thrust forward with more force.
- Stability of the project. This was a major concern because of the height of the device. The device had to be stabilized at the bottom
- Reliable results. There was a problem with getting the projected ball to land within the range of the sensors every time. Part of the problem was solved by providing a grooved channel for the ball to be placed in. The path of the ball was also determined by numerous trials after the device was stabilized.

### ***Results***

The solenoids were able to release the balls simultaneously and the program executed the timing. Like we expected there were very slight variations in the time both balls hit the platform. Approximately three out of ten times it missed the target totally. The reality is that this was not a precision device and many variations could have played a part in our results including:

- Slight differences in air density creating “drag”
- Slight differences in the way the plunger of the solenoid hits the ball
- Slight differences in the curvature of the ball

This experiment clearly illustrates Sir Isaac Newton first two laws. In his own words -

*Law I – “Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impress'd thereon”*

*Law II – “The alteration of motion is ever proportional to the motive force impress'd; and is made in the direction of the right line in which that force is impress'd” (Microsoft Encarta, 2007).*

Projectile motion formulas include the following:

$$\triangleright d = v_i t + \frac{1}{2} a t^2$$

- (for horizontal and vertical motion, d can be substituted for x and y respectively), ex:

$$\circ x = v_{ix} t + \frac{1}{2} a_x t^2 \qquad \qquad y = v_{iy} t + \frac{1}{2} a_y t^2$$

$$\triangleright v_f^2 = v_i^2 + 2ad$$

$$\triangleright v_f = v_i + at$$

Using the data from 5 trials, the average results were as follows:

	Distance Dropped	Time Taken to Hit the Channel
Projected Ball	0.162 m	0.62 sec
Free-falling Ball	0.162 m	0.71 sec

Finding the final velocity we used:

Projected ball

$$v_f = v_i + at$$

$$v_f = 6.08 \text{ m/s}$$

Free-falling ball

$$v_f = v_i + at$$

$$v_f = 6.96 \text{ m/s}$$

***Implications for Further research:***

- Solenoid/voltage in solenoid could be varied so that the ball could be projected to various horizontal distances.
- Another device could be created identical to the first one, then they could be placed face-to-face and could be programmed to have the projected balls hit each other at a specified time.
- The height of the device could be modified to determine if height affects the outcome.
- The mass or weight of the balls could be varied.

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