Physics 12 +
Physics 11 H

Investigation 1: FORMAL LAB

Projectile Motion

Most types of motion that occur in nature are far more complex than the straight line motion you have studied so far. The motion of a projectile can best be studied as the sum of two components of motion – one vertical and one horizontal. First, however, you must make a record of the motion.

This method involves using an air table to create a ~~strobe photo~~ spark graph of a moving disc for analysis.

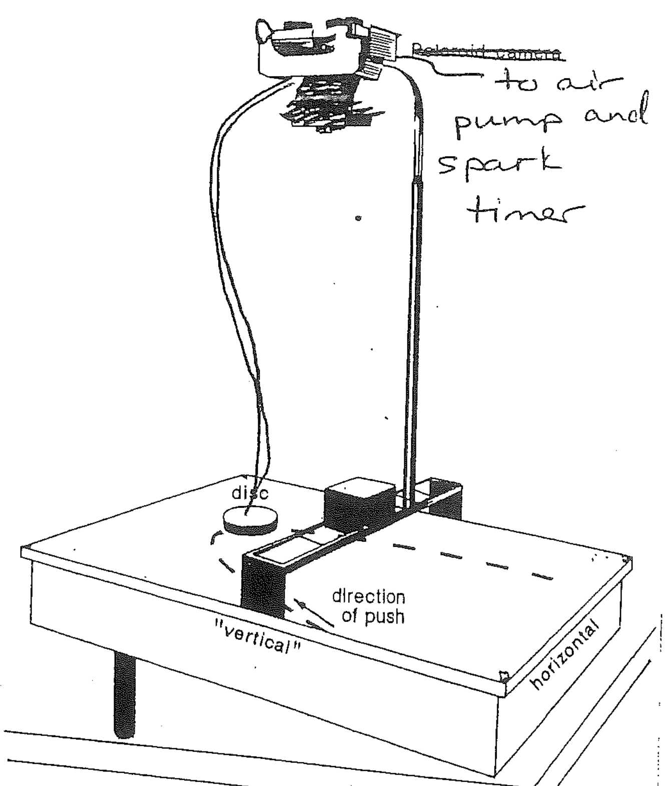
Apparatus

- air table and disc
- ~~strobe light~~ spark timer
- ~~Polaroid camera~~ paper
- carbon paper

Procedure

1. Tilt an air table slightly so that when the air puck is pushed as shown it will travel up the air table and then down again. (See Figure #001.)
2. Set the timer to 50 Hz
3. ~~Obtain a spark graph of the motion~~

#001 Air table and disc

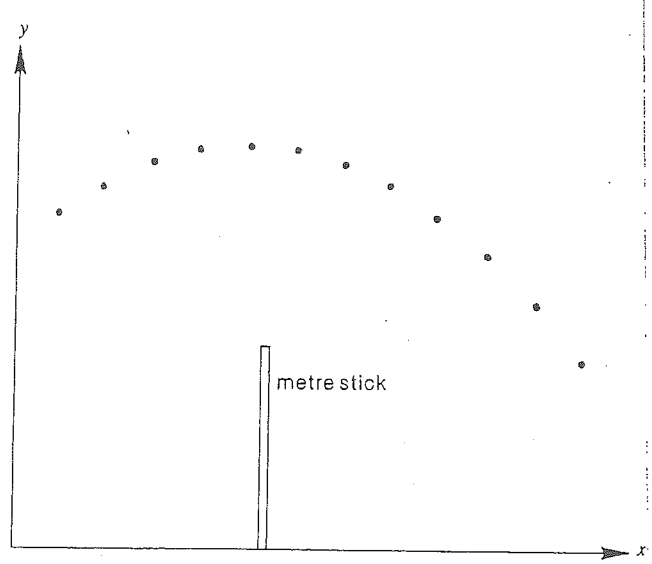


↑ this is similar to the equipment we'll use.
(not exactly the same as our equipment!!
you must draw a new diagram of our actual equipment)

Analysis of Spark Graph of Motion

The following diagram (#003) represents a strobe illustration of a ball thrown upwards at an angle to the horizontal.

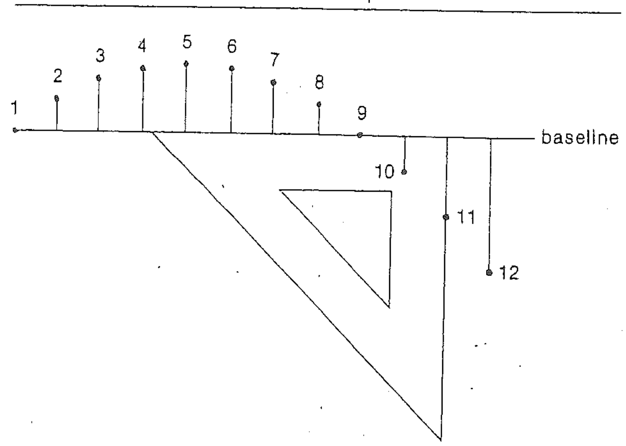
#003 Strobe illustration of the path of a projected ball.
Strobe frequency = 15 Hz.



This motion can be analysed using the following procedure:

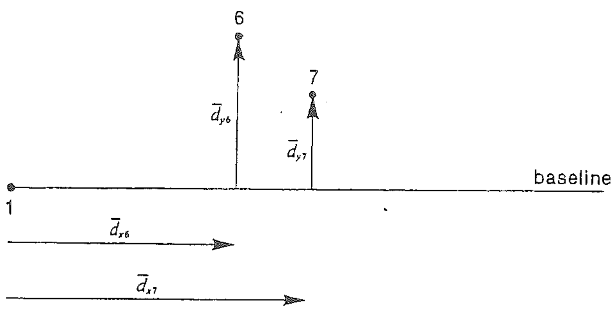
1. number the successive positions of the ball.
2. draw a line through the centre of the leftmost ball's position, parallel to the horizontal (this will be called the baseline).
3. Use a plastic right-angled triangle to draw lines from the baseline to the centre of each position of the ball as shown in figure #004.

#004 Analysing the motion of a ball: Step 3



4. For each spark, measure the horizontal and the vertical components ($\vec{d}_x$ and $\vec{d}_y$) of the ball's displacement from its original position. (Use + for upward displacements and − for downward.)

#005 Analysing the motion of a ball: Step 4



$\Delta\vec{d}_y = \vec{d}_{y7} - \vec{d}_{y6}$ and $\Delta\vec{d}_x = \vec{d}_{x7} - \vec{d}_{x6}$

5. The average vertical velocity of the ball between sparks can then be calculated by dividing $\Delta\vec{d}_y$ by [redacted], the time between the flashes.

Although this value is the *average* vertical velocity between flash 6 and flash 7, it can be expected to be very close, if not equal, to the *instantaneous* vertical velocity midway in time between flash 6 and flash 7.

You can calculate the instantaneous horizontal velocity midway in time between two flashes in a similar way from $\Delta\vec{d}_x$.

6. Make a table with the following headings (see table #006).
   - t time measured in flashes of the strobe
   - $\vec{d}_y$ vertical component of the displacement of the ball from its original position
   - $\vec{v}_y$ vertical component of the ball's velocity midway between flashes
   - $\vec{d}_x$ horizontal component of the displacement of the ball from its original position
   - $\vec{v}_x$ horizontal component of the ball's velocity midway between flashes

List $\vec{d}_x$ and $\vec{d}_y$ for successive images of the ball. Calculate $\vec{v}_x$ and $\vec{v}_y$ from $\Delta\vec{d}_x$ and $\Delta\vec{d}_y$ and add them in.

#006 Table of variables

t (s)	$\vec{d}_x$ (cm)	$\vec{d}_y$ (cm)	$\vec{v}_x$ (cm/s)	$\vec{v}_y$ (cm/s)
0				
1/60				
2/60				
3/60				
4/60				

7. Graph (a) $\vec{d}_x$ vs. t, (b) $\vec{d}_y$ vs. t, and (c) $\vec{v}_y$ vs. t. [redacted]

8. Find the mathematical equation for each of your graphs (equation for d_y vs t graph is bonus)

Discussion of Results

1. Is the horizontal velocity of a projected ball constant? Use your graphs to support your explanation. What is the horizontal acceleration of a projectile?

2. Use the horizontal and vertical components of velocity to calculate the vector velocity of the projected ball or disc midway in time between any two consecutive flashes.

3. You know the general equations for uniformly accelerated motion:

$$v = v_i + at$$
$$d = v_i t + \tfrac{1}{2} at^2$$

where v and d are the instantaneous velocity and displacement of the object from its original position at time t, v_i is the initial velocity of the object, and a is its acceleration. Applying these equations to the x and y components of the motion of a projectile, we expect

$$v_y = v_{yi} - at$$
$$d_x = v_{xi}t \qquad d_y = v_{yi}t - \tfrac{1}{2}at^2$$

How do the equations of your graphs compare with these equations? [redacted]

4. How would you describe the variation with time of a projectile's
   (a) horizontal velocity?
   (b) vertical velocity?
   (c) vertical acceleration?

In questions of science the authority of a thousand is not worth the humble reasoning of a single individual.
Galileo Galilei

Practice Problems

Note: Throughout this book, assume that all zeroes not clearly significant are, in fact, significant.

1. A ball is dropped from a height of 80.0 m. How long does it take to fall?
2. A ball is thrown horizontally at a speed of 40.0 m/s from a cliff 80.0 m high.
   (a) How long does it take to strike the ground?
   (b) How far horizontally does the ball travel before striking the ground?
3. A golfball is driven at a speed of 80.0 m/s at an angle of 40.0° from the ground. Disregard any effects due to air resistance.
   (a) What is the vertical component of the initial velocity?
   (b) What is the horizontal component of the initial velocity?
   (c) How long will the ball be in the air (if you assume that the ball strikes the ground at the same level as it leaves the ground)?
   (d) What maximum altitude will the golfball reach?
   (e) How far will the golfball go horizontally before striking the ground?
4. A stone is fired from a slingshot at an angle of 65° from the horizontal. The stone strikes the ground 8.0 s later at an altitude 30.0 m lower than the height at which it was released.
   (a) At what initial velocity was the stone released?
   (b) How far horizontally does the stone go before striking the ground?
5. ~~Two archers are trying to hit a distant target. One shoots at a low angle, thinking that such a shot will be more accurate. The other shoots at a greater angle, expecting to attain greater distance. If you assume that they both shoot at the same initial speed, show that they could both hit the target. Also show that the two angles add up to 90.0°~~

VELOCITY — EXAMPLE OF MEASUREMENTS USING THE AIR TABLE WITH SPARKER TIMER

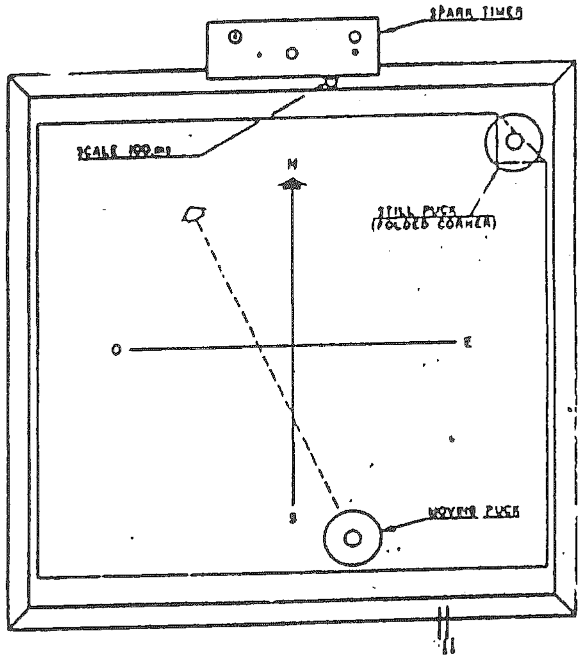
Brief Discussion

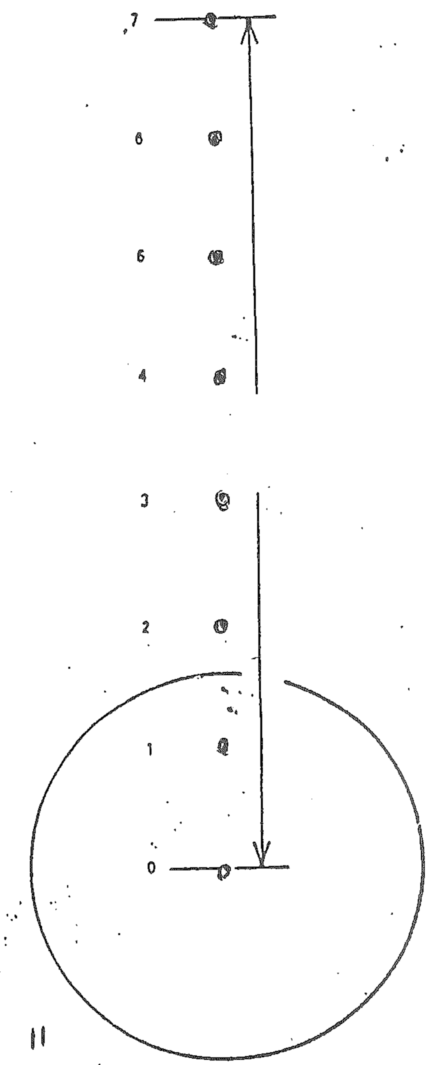
The "time" of the air table is variable and allows us to measure identical instances with varying degrees of accuracy. For some experiments too many dots only provide tedious and unnecessary calculations. For other very quick experiments, such as acceleration due to gravity, a very fast speed (10 ms) is needed, in order that enough data be procured. If only 3 or 4 dots are made an accurate study is not possible.

Experiment I — Uniform Motion

Purpose: To introduce the concepts of uniform motion (Newton's First Law).

Method: Level off the table as much as possible. Attach the puck shooter on the front of the table (puck shooter not necessary). Place one puck in the top right hand corner on a folded piece of paper (only one puck is used for this experiment). Shoot the other puck and simultaneously activate the sparktimer. Both pucks must be on the paper to complete the circuit.





SPARKTIMER — 100 ms

CALCULATIONS

$d = 16.9$ cm

$t = 7 \times 100$ ms $= 7 \times .1$ sec
$= 0.7$ sec

$v = \frac{d}{t}$

$= \frac{16.9 \text{ cm}}{.7 \text{ sec}}$

$= 23.86$ cm/sec

UNIFORM MOTION

(1)

Brief Discussion

In studies of this type of motion, the students question the reality of whether or not horizontal and vertical motion are independent of one another.

Given the problem of a person dropping a bullet and of firing a bullet horizontally. They don't seem to believe that the two, theoretically, should drop to the earth at exactly the same time.

The situation is to show that vertical and horizontal motions are independent. A projected puck can be analyzed vectorily. The horizontal motion shows uniform velocity (Vx) and the vertical motion shows acceleration motion (Vy) these vertical motions can be resolved to correspond with the actual vectorial projected motion (V_r) vector of the puck.

INDEPENDANCE OF VERTICAL AND HORIZONTAL MOTIONS