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Investigation 1.4.1: Investigating Projectile Motion

INQUIRY SKILLS

- ○ Questioning
- ● Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

There is a danger of electrocution. Leave the spark generator off until you are ready to gather data. Do not touch the air table when the spark generator is activated.

To prevent an electric shock, the two pucks must be in contact with the carbon paper whenever the sparker electricity is activated.

Keep the angle of the air table above the horizontal very small.

A convenient way of analyzing projectile motion uses an air table in which friction between the moving puck and the surface is minimized (**Figure 1**). If the table is elevated along one side, then a puck that is launched with a horizontal component of velocity will undergo projectile motion. You can analyze that motion using a combination of diagrams and equations.

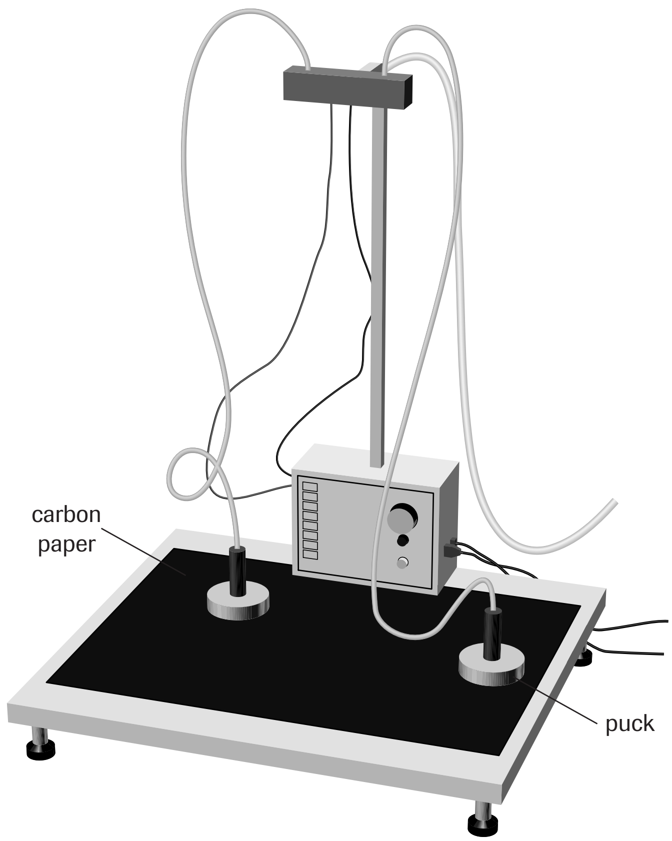

Figure 1
When using an air table with a sparker puck, keep another puck near the edge of the table in contact with the carbon paper to prevent a break in the current to the sparker.

Questions

(i) What is the direction of the acceleration of a projectile on an inclined plane?

(ii) How can you show that the vertical component of projectile motion on an inclined plane is independent of the horizontal component?

Hypothesis

(a) Hypothesize answers to both questions. Explain each answer.

(continued)

Materials

For the class:
air table and related apparatus
bricks or books to support the raised end of the table

For each group of 4 or 5 students:
metre stick

For each student:
3 sheets of construction paper
centimetre ruler
protractor

Procedure

1. Working in a group, determine the angle of incline of the air table as accurately as possible. (Apply trigonometry.)

2. With the sparker turned off and the air supply turned on, have one person in the group ready to stop the puck before it hits the edge of the table. Practise setting one of the pucks in motion to satisfy each of the following conditions:
   Motion A: $v_{ix} = 0$; $v_{iy} = 0$
   Motion B: $v_{ix} > 0$; $v_{iy} = 0$
   Motion C: $v_{ix} > 0$; $v_{iy} > 0$
3. When you are satisfied with the motions and with the safe use of the apparatus, turn on the sparker and create Motions A, B, and C on separate pieces of the construction paper for each member of the group. (Do not touch the air table when the spark generator is activated.) Label each motion, indicating the frequency and period of the sparker.

   Note: For the remaining steps, neatness and accuracy are very important.
4. For the linear motion (see **Figure 2**, Motion A), draw between 6 and 10 velocity vectors, $\vec{v}_1, \vec{v}_2, \ldots \vec{v}_n$, by drawing displacement vectors and dividing each one by the time interval for the displacements. Use vector subtraction to determine the corresponding $\Delta\vec{v}$ vectors, as illustrated in the diagram.

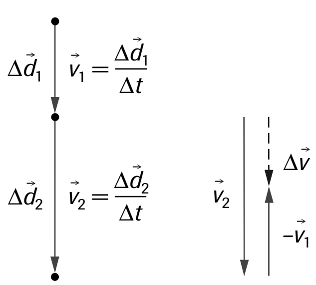

Figure 2
Determining the change in velocity for frictionless motion on an inclined plane

(continued)

Next, calculate the average acceleration for each $\Delta\vec{v}$ vector, using the equation

$$\vec{a}_{\mathrm{av},n} = \frac{\vec{v}_{n+1} - \vec{v}_n}{\Delta t}$$

where Δt is the time interval from the mid-time of $\vec{v}_n$ to the mid-time of $\vec{v}_{n+1}$. Finally, calculate the average acceleration of all $\vec{a}_{\mathrm{av},n}$ values.

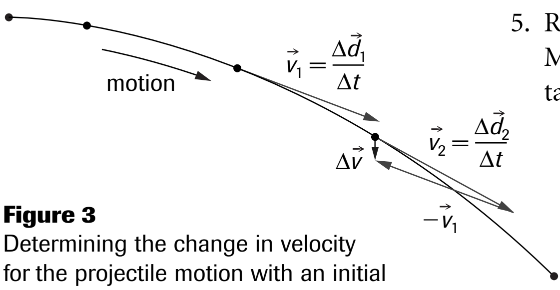

Figure 3
Determining the change in velocity for the projectile motion with an initial horizontal velocity

5. Repeat step 4 for the motion with an initial horizontal velocity (see **Figure 3**, Motion B). Ignore sparker dots created when the pushing force was in contact with the puck or created after the puck came near the edge of the table.

(continued)

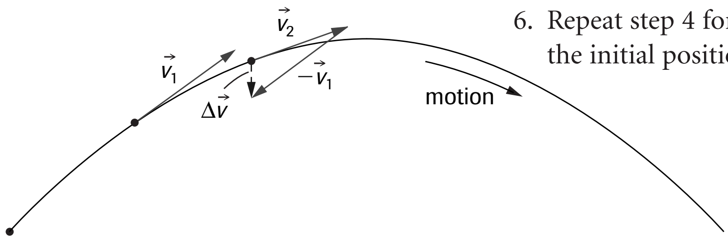

Figure 4
Determining the change in velocity for the projectile motion with an initial velocity at an angle to the horizontal

6. Repeat step 4 for the motion in which the puck was launched upward from the initial position (see **Figure 4**, Motion C).

Analysis

(b) Compare the magnitudes and directions of the accelerations for the three motions tested in this investigation.

(continued)

(c) Use the angle of the table, θ, to determine the magnitude of the acceleration down the inclined plane. (*Hint:* Use the equation $a = g \sin \theta$, where $g = 9.8 \text{ m/s}^2$.)

(d) Find the percent difference between your answer in (c) and each of the other average accelerations.

(continued)

(e) Answer questions (i) and (ii).

Evaluation

(f) Comment on the accuracy of your hypothesis.

(g) Describe random and systematic sources of error in this investigation. How could you minimize these sources of error?

(continued)

Synthesis

(h) In analyzing the vectors of the motions in this investigation, is it better to use smaller or larger values of Δt? Give your reasons.

(i) Explain why you were asked to calculate the percent difference rather than the percent error in (d).

(j) Prove that the equation $a = g \sin \theta$ is valid for the magnitude of the acceleration down a frictionless plane inclined at an angle θ to the horizontal.