Investigation 1.4.1 Investigating Projectile Motion

- In this investigation, students produce air table tracks that represent three examples of projectile motion. Students analyze the tracks and identify common characteristics. Students then compare a theoretical value for the acceleration on the air table with the value they determined experimentally.

BACKGROUND INFORMATION

The motions of all projectiles have one feature in common: their acceleration. Since the only force acting on a projectile is the force of gravity, all projectiles have a vertical acceleration of 9.8 m/s^2 (in the absence of air resistance). As well, their horizontal motion is uniform since no forces typically act in the horizontal direction. In this investigation, an air table is tilted at a slight angle and an air puck is sent across it, producing a tracing of dots. An analysis of the dots along two planes—one parallel to the inclination and one perpendicular to it—demonstrates the typical attributes of projectile motion. The angle of inclination serves to dilute the effect of gravity. In this investigation, the force acting on a projectile in flight is the force of gravity acting parallel to the slope of inclination ($F_g \sin \theta$, where θ is the angle of inclination of the air table.). As such, the acceleration of the air puck is the corresponding component of the acceleration of gravity ($g \sin \theta$).

Related Background Resources

- Air table instruction manual
- *Nelson Physics 12*, Section 1.4, pages 41–39

Teacher Preparation

Time: 20 min

Instructional Resources

- Textbook Investigation 1.4.1
- Lab and Study Master: Student Worksheet LSM 1.4-1 Investigation 1.4.1 Investigating Projectile Motion
- Solutions Manual
- Appendix A2: Planning an Investigation
- Appendix A5: Lab Reports

Material/Equipment	Quantity per station	Quantity for 16 stations
1 or 2 air tables and related apparatus with books or bricks to incline the table(s) slightly		n/a
newsprint for tracings	3 sheets per student	n/a
metre stick	1 per group	n/a
protractor	1 per student	n/a
centimetre ruler	1 per student	n/a

Materials and Equipment Notes

- The air table must be handled with great care and caution. It is a very expensive piece of equipment and somewhat delicate in nature. When the air table is inclined, the angle of inclination needs to be only 5° or 10°. The teacher should set up the table ahead of time and test the apparatus for optimum performance. The teacher also must ascertain how the students will launch and catch the projectiles in a safe manner. (There are commercially available launching devices for this type of laboratory procedure.)

- Students should be aware of the potential shock hazard associated with an air table (newer models operate on far less voltage). A discussion of the circuit involved will alert students to the potential shock risks when the spark timer is operating. Students must not touch the air table itself or any metallic parts of the air pucks while the spark timer is operating. The air hoses are also a potential source of electrical shock if the fine chain inside the air hose gets close enough to a student's skin.
- The compressor that feeds air to the pucks should be positioned so that the vibrations it produces do not affect the motion of the air pucks. The air hoses should not become entangled with one another.

Safety and Disposal

- As previously noted, there is the potential for receiving an electrical shock if students touch any conductive part of the air table when the spark timer is operating. Students must be made aware of this potential hazard.

Assessment

- This investigation involves considerable analysis of the data collected. Using parts of Assessment Rubric 2: Inquiry is appropriate (Teacher's Resource).
- The use of Assessment Rubric 3: Communication is appropriate if the students are expected to submit a formal lab report (Teacher's Resource).

Student Preparation

- Students require a good working knowledge of projectile motion to comprehend the required calculations and analysis involved in this investigation.
- Although most students will have used an air table before, a thorough review of its operation and potential hazards is necessary for safety reasons.
- A projectile motion tracing of "motion C' can be generated by the teacher, copied, and distributed to the students prior to class so that students are familiar with the analysis that is required.

Pre-lab Discussions

- A complete review of the operation and care in operating an air table is necessary.
- Discuss the analysis that is required for this investigation, perhaps doing some sample calculations.
- Review projectile motion and the purpose of inclining the air table.
- Discuss the necessity for precise measurements in this investigation.
- Review how to properly draw tangents to a parabolic curve (refer to the text on page 13).

During the Lab

- The teacher must carefully monitor students when they are operating the air table, paying particular attention to the potential shock hazards.
- Once the students have completed their tracings, the teacher should monitor their analyses of the tracings and answer any questions they may have.
- While the students are performing the investigation, the teacher should be prompting them to identify sources of systematic and random errors.

Post-lab Discussions

- A general discussion of the results with the entire class is in order. The class should have consistent results for the acceleration values, provided the air table had the same inclination for all groups.

- A discussion of experimental error is useful at this point. Ask students to identify changes they would make to the design or procedure, or both, associated with this investigation.
- Students may want to refer to Appendix A2 on page 764, and Appendix A5 on page 768.

Extensions/Modifications

- If time is an issue, the teacher can demonstrate how a tracing is made using this apparatus, and produce and photocopy one (or more) sample tracing for the students to analyze.
- If an air table is not available, a videotape (or photograph) can be made of a projectile with both a vertical and horizontal grid placed behind the flight path (using metre sticks or a grid on paper). Measurements can be taken directly from the videotape (or photograph).
- The projectile can be videotaped and replayed in slow motion to illustrate its parabolic path.

Lab Exercise 1.4.1 Hang Time in Football

- When the punting team kicks a football, it is to their advantage if the range is as great as possible to force the opposing team as deep downfield as possible. At the same time, the kicking team wants to arrive at or near the ball as it reaches the ground. Therefore, it is also desirable to maximize the flight time. The flight time increases with the angle of projection, but the horizontal range decreases when this angle is either above or below 45°. As a result, the optimum kick combines a long horizontal range with a large flight time. This investigation provides sample data for a number of football kicks. The horizontal range can be plotted as a function of the flight time for a variety of launch angles to help students decide which combination is best. The launch speed is constant for all kicks.

BACKGROUND INFORMATION

For a projectile that returns to the same horizontal level from which it is launched ($\Delta y = 0$), the flight time $\left(\Delta t = \frac{2v_i \sin\theta}{g} \right)$ and the horizontal range $\left(\Delta x = \frac{v_i^2 \sin 2\theta}{g} \right)$ depend entirely on the speed and angle of launch. Thus, an optimum kick gives a football a long flight time and a large horizontal range.

Related Background Resources

- *Nelson Physics 12,* Section 1.4, pages 41–39

Teacher Preparation

Time: 5 min

Instructional Resources

- Textbook Lab Exercise 1.4.1
- Lab and Study Master: Student Worksheet LSM 1.4-2 Lab Exercise 1.4.1 Hang Time in Football
- Solutions Manual
- Appendix A2: Planning an Investigation
- Appendix A5: Lab Reports