Economy Air Track

P4-2710

INSTRUCTIONAL GUIDE

Contents

- Air track
- Air source
- Two gliders
- End pulleys
- Brackets
- Masses
- Collision kit
- Digital timer and 2 photogates
- Instructional Guide and Assembly Guide

Background

This 1.2 m track creates a nearly frictionless surface to carry out kinetics experiments with gliders. The apparatus is perfect for demonstrating fundamental classical physics concepts like force, motion and conservation of energy, and momentum. Hand the reigns over to the students and let them test Newton's Laws of Motion or experiment with velocity, acceleration, and collisions.

The Air Track Apparatus relies on a "cushion" of air created by the flow of air pumped through the hollow track and then out small holes along its upper surfaces. This air flow, provided by an included air source, gently lifts the glider and allows it to slide along the track with minimal friction. When the included air-cushion lubricating reagent is also used, the glider experiences virtually no loss of energy when sliding along the track.

Introduction

Safety:

- An instructor should be present when the apparatus is in use.
- To prevent minor injury, avoid touching the track when a glider is in motion.
- If a glider moves too quickly, it may fly off the track.

Care and Maintenance:

The fit between the track and gliders is very precise, and the apparatus will not work well if either is damaged. In order to maintain this exact, friction-free surface, follow these care instructions:

- Handle the track and the gliders with extreme care during set-up, use, and transport.
- Test the holes along the track before use by turning on the air source and feeling for air. If any holes are blocked, use a 0.5 mm steel needle to clear the debris.
- Avoid placing gliders on the track when the air source is turned off.

- Maintain glider speeds of 50 cm/second or slower.
- After use, wipe the surface of the track with a clean, dry cloth to remove lubricant and dust.
- Store the air track and its component parts in a dry area away from corrosive liquids and/or gasses.
- During storage, hang the track vertically to prevent bending.
- The caps at either end can be removed for cleaning inside the track.

Major Components:

The air track, is precisely machined out of aluminum. When air is pumped through the air track and a glider is set on top, a cushion of air forms between the track and the glider such that the glider can slide along the track with minimal friction. A measuring tape along the track can be used for various calculations. The air source is a small air compressor that provides the air pressure necessary to create an air cushion between the track and glider. Count, velocity, acceleration, periods, and intervals can be determined when used with the photogates and digital timer.

Basic Setup:

1. Choose a level and stable surface for the Air Track.
2. If you will be using the pulley attachment, arrange the Air Track so that the air source attachment end is on the table and the opposite end hangs slightly over the edge of the table.
3. Attach the track to the base and attach the rise washer and rise washer foot to the support on the other end of the track.
4. Adjust the two screws on the base so that the track looks as level as possible. More precise leveling can be completed once the air source is attached and turned on.
5. Set up the mini-air source on the floor or on a separate table to prevent vibrations from affecting movement of the gliders on the air track.
6. Attach the mini-air source to the air track apparatus and turn on.

Testing the Apparatus:

1. Test for air flow along the track.
    a. With the air source turned on, use a finger to feel for air flow at each of the holes along both surfaces of the air track.
    b. Turn off the air source and use a 0.5mm wire or needle to clear any debris that may be blocking a hole.
2. Level the track.
    a. Turn on the air source.
    b. Gently set a glider on the track.
    c. Turn the rise washer to adjust the track up or down until the glider remains at rest or until it slides only slightly and not always in the same direction.

Set Up the Photogates: Please Note the timer performs best when fully charged

1. Mount the photogates on the track
2. Plug the photogates into the input sockets on the side of the digital timer.
3. Plug in the digital timer into an outlet and turn on.

Activities

Newton's First Law of Motion:

Newton's First Law of Motion states that an object at rest stays at rest and an object in motion stays in uniform motion unless it is acted upon by an unbalanced force. The tendency for an object to stay unchanged—either at rest or in motion—is known as inertia.

Points of Investigation:

Constant Velocity:

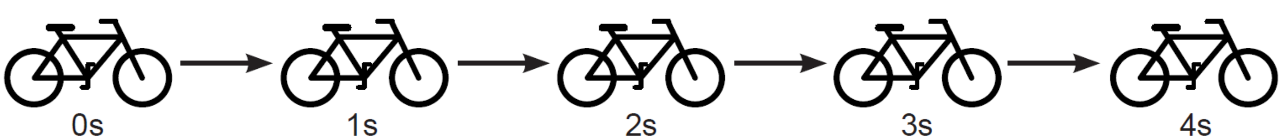
- Check the velocity of a moving glider at two points along track using the photogates.
- Does the glider accelerate? Decelerate? Maintain a constant velocity?
- Identify any forces acting upon the glider while it is in motion.
- *Discussion Question:* How does this demonstrate Newton's First Law of Motion?

Graphing Alternative:

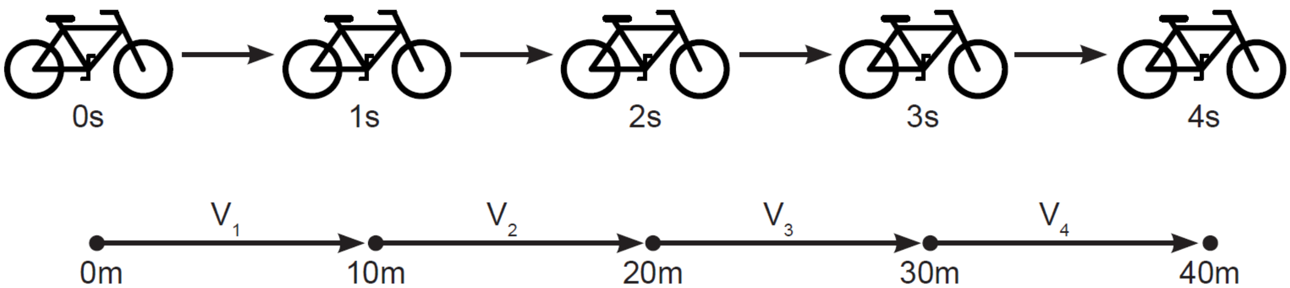
- Graph the data as position versus time and draw a motion diagram.
- Video record the motion of a moving glider as it slides along the track.
- Measuring tape should be in focus for measurements to be taken.
- Review the video frame by frame, and record the position of the glider at each unit of time.
- Create a line graph with time on the x-axis and distance on the y-axis.
- Draw a motion diagram of the event.
- *Discussion Questions:*
    - What does the diagram and/or graph tell you about the motion of the glider?
    - How does your data demonstrate Newton's First Law of Motion?

Motion Diagrams:

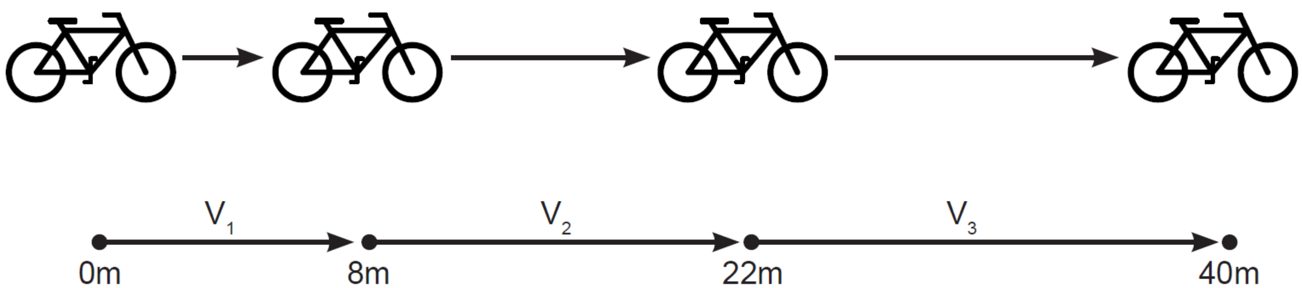
Motion diagrams are a visual way to depict the direction and relative magnitude of a vector, such as velocity or acceleration. Imagine a camera taking pictures of a moving object at a constant rate. Say one picture per second. These pictures could be superimposed to create a simple motion diagram.



Each arrow represents a distance moved over a period of time, or the velocity of the bicycle at each point. Note that, in this case, the arrows are uniform. The velocity stays the same throughout the motion diagram. The diagram could be further streamlined to just consist of the arrows representing the velocity vectors.



As an object accelerates (in a positive or negative direction), the velocity vectors will increase (or decrease) in length as well.



Motion diagrams can be useful in visualizing and understanding what is happening to an object in motion.

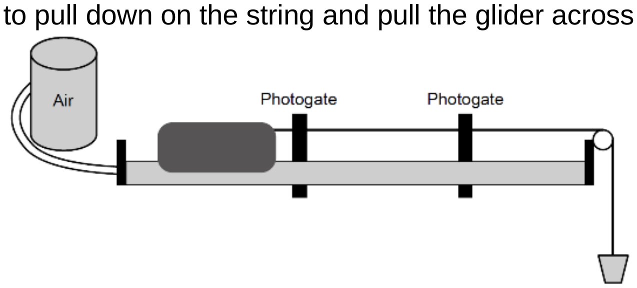
Newton's Second Law of Motion:

Newton's Second Law of Motion states that the acceleration of an object is directly proportional to the net forces acting upon it and indirectly proportional to the mass of the object. In other words, acceleration is equal to the net force acting upon an object divided by its mass, or $a = F_{net}/m$.

<u>Points of Investigation:</u>

Effect of constant force on an object/system:

- Set up the air track with two photogates and a pulley attached to the end of the track. Tie the end of a piece of string to a glider and the other end to the weight bucket. Thread the string over the pulley and hold the glider in place at the other end of the track. Release the glider, allowing the weight bucket to pull down on the string and pull the glider across the track.



- Measure the velocity of the glider at the two photogates. What is happening?
- Alternative: video record the event and measure how far the glider travels in each frame (time).
- Draw a diagram of the forces acting upon the glider to explain your observations.
- Determine the acceleration of the glider due to the constant force of the weight bucket pulling on it.
    - $a = \Delta v / \Delta t$

Relationship between force, mass, and acceleration:

- Run the investigation several times, changing the mass and force to determine their effects on acceleration.
- Try adjusting force by adding mass to the weight bucket. Test several times by increasing mass to the bucket a little at a time. Graph your results with force on the x-axis and acceleration on the y-axis.
- Try adjusting mass of the glider by adding masses using hexagonal screws. Keep the weight bucket mass constant. Test several times by increasing mass a little at a time. Graph your results with mass on the x-axis and acceleration on the y-axis.
- *Discussion Questions:*
    - How does increasing mass in the bucket affect acceleration?
    - How does increasing mass of the glider affect acceleration?
    - Do your results support Newton's Second Law of Motion?

Test Newton's Second Law of Motion by using the equation F = ma to predict acceleration:

- Determine the net force acting upon the glider.
    - The net force acting upon the glider is the force of the weight bucket (and any masses inside the bucket).
    - All other forces in the system are cancelled out, so $F_{net} = F_{weight}$ bucket
    - $F_{net} = m_{weight}$ bucket * g (where g = acceleration due to gravity)
    - $F_{net} = m_{weight}$ bucket * 9.8 m/s^2
- Calculate the expected acceleration for the glider.
    - F_{net} = (m_{weight} bucket + m_{glider}) * a
    - Note that when solving for acceleration, we include all of the mass in the system, and not just the mass of the glider.
- Compare the calculated acceleration to the experimental acceleration of the glider.
- Try adding masses to the weight bucket or the glider and repeat. Be sure to start the glider from the same location along the air track each time.
- *Discussion Questions:*
    - Why might there be a difference between the predicted acceleration and the experimental acceleration?
    - Do your results verify Newton's Second Law of Motion? Why or why not?

Negative acceleration:

- Set up the air track on an incline. Start the glider near the bottom of the incline and give it an initial push to get it started up.
- Use the photogates or video recording to determine velocities and acceleration. Graph video data. What happens? How would you describe the acceleration?
- *Discussion Questions:*
    - How would you describe the acceleration of the glider in this investigation?
    - Explain your observations using Newton's Second Law of Motion.

Conservation of Energy:

The theory that energy is conserved is a basic tenet of science and can be tested using the Air Track Apparatus.

Points of Investigation:

Total Mechanical Energy:

- Use an inclined air track to compare the kinetic energy and potential gravitational energy as the glider slides down the track.
- If energy is conserved, and if the initial velocity is 0, the final kinetic energy (KE_{final}) should be equal to the initial Potential Energy due to gravity ($GPE_{initial}$).
- $KE=1/2mv^2$
- $GPE=mgh$ (where g = gravitational acceleration [9.8 m/s^2] and h = height)
- To test for conservation of total mechanical energy, set $KE_{final}= GPE_{initial}$ and solve for velocity. Use the air track, a ruler, and a photogate at the bottom of the track to experimentally test the final velocity. To simplify, say that h = 0 at the photogate.
- To further explore the Conservation of Energy, test for velocity along several points of the inclined track. Graph or otherwise examine the relationship between potential gravitational energy and kinetic energy as the glider moves downward.
- *Discussion Questions:*
    - Does the mass of the glider matter in this investigation? Why or why not?
    - Does the incline angle of the air track matter in this investigation? Why or why not?

Newton's Third Law of Motion:

Newton's Third Law of Motion states that for every action, there is an equal and opposite reaction. The Air Track apparatus is perfect for exploring a variety of these reactions.

Points of Investigation:

Elastic Collisions:

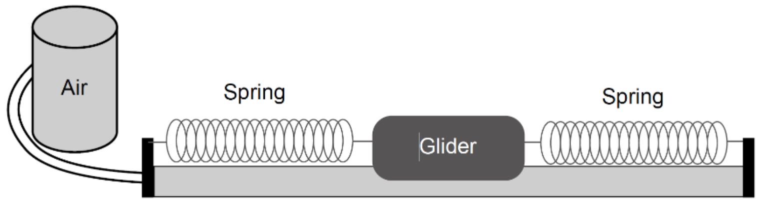
- Using the bumper on one of the gliders, observe how the gliders behave when they collide (with the bumper between them). Make predictions about the expected behavior before carrying out the investigations.
    - When a moving glider collides with a stationary glider
    - When one glider is moving and a second glider is moving in the same direction but at a higher speed.
    - When both gliders are moving in opposite directions at the same speed and at different speeds.
- Attach additional masses to the glider. Repeat your predictions and experiment.
- *Discussion Question*: How do your observations demonstrate Newton's Third Law of Motion?

Inelastic Collisions:

- Attach the Velcro loop plate on one glider and the Velcro hook plate on the other so that the gliders stick to one another when they collide.
- Repeat the investigations described for elastic collisions.
- *Discussion Question*: How do your observations demonstrate Newton's Third Law of Motion?

Simple Harmonic Motion:

By placing a glider on the air track and connecting it to two springs of spring constant k, several concepts of harmonic oscillation can be studied.



<u>Points of Investigation:</u>

Period and Amplitude

- Push the glider approximately 25cm to one side or the other and release. What happens?
- Determine experimentally if and how the period (T) of the oscillation is dependent or independent of amplitude (maximum displacement from equilibrium). The period of the oscillation is the amount of time for the glider to complete one complete oscillation. If a photogate is located at the position of equilibrium, the glider will pass through the gate twice in one period. Try amplitudes of 10cm, 20cm, 30 cm, etc.
- *Discussion Questions:* The equation to determine the period (T) of a simple harmonic oscillator is $T = 2\pi\sqrt{(m/k)}$. Do your results fit with this equation? How so?

Period and Mass

- By experimenting with differing quantities of masses on the glider, determine how the mass of the glider affects the period of oscillation.
- *Discussion Questions:* Do your results fit with the equation $T = 2\pi\sqrt{(m/k)}$? How so?

Spring Constants

- Using your experimental data from studying the relationship between period and mass, solve for the spring constant
  - $(k)T = 2\pi\sqrt{(m/k)}$
  - Because there are two springs, $k_{system} = k_1 + k_2$. The constant for each spring will vary slightly, so you can only effectively solve for k_{system}.
  - The mass of the system also includes, to some degree, the mass of the springs. In this case, the effective mass of each spring is $m_{spring}/3$. Therefore $m_{system} = m_{glider} + m_{spring1}/3 + m_{spring2}/3$.
- *Discussion Question*: If the spring constant doubled, how would this affect the period?

Graphing Simple Harmonic Motion

- Video record the oscillating movement and watch it frame-by-frame to collect measurement data on where the glider is from center in relation to time. Plot the data on a graph with time on the x-axis and distance from center (positive or negative) on the y-axis. What do you notice?
- What other objects demonstrate simple harmonic oscillation?

NGS Standards

MS-PS2-1 - Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects

MS-PS2-2 - Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS3-1 - Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-5 - Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

HS-PS2-1 - Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-2 - Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS3-2 - Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

Related Products

Air Puck Physics Kit (P4-2155) Our exclusive Air Puck Physics Kit includes two pucks, inelastic collision kit, and puck launcher.

Collision in Two Dimensions Apparatus (P2-8450) The Collision in Two Dimensions Apparatus allows students to experience the conservation of momentum and kinetic energy by investigating the difference between elastic, inelastic, and partially elastic collisions.

Mini Air Puck (P4-2140) The always popular air-puck now comes in compact form! The Air Puck, famous for its nearly frictionless motion, glides across a cushion of air letting you conduct demonstrations of Newton's Laws, energy, and momentum with a higher degree of consistency and accuracy.