sci-supply

SCI-SUPPLY SS1701
AIR TRACK WITH ACCESSORIES

1. INTRODUCTION

The Sci-Supply SS1701 Air Track is a complete set of experimental apparatus for the study of linear motion. The main component of the set, the air track, is a closed hollow channel, the top surfaces of which form an inverted “V”. These finely-machined surfaces are very straight and smooth, and have a series of small holes drilled through to the inside of the channel. With positive air pressure supplied to the channel, a stream of air spills out of each hole. A glider with mating inverted “V” bottom surfaces, when placed on the air track, will then be supported by a cushion of air, and glide along the track with negligible friction. A full compliment of accessories is included in the set, to facilitate the study of such physical phenomena as:

- Constant velocity under zero external force,
- Acceleration under the influence of gravity or an external force,
- Exchange and conservation of momentum,
- Elastic and inelastic collision,
- Exchange and conservation of energy,
- Simple harmonic motion.

The assembled apparatus is shown in Figure 1.1. Accessories are shown in Figure 1.2. A photogate digital timer (Sci-Supply SS20120) and a blower / air supply (Sci-Supply SS1702) are also required to use the apparatus. A complete set with air track, blower / air supply and photogate digital timer is also available (Sci-Supply SS1700)

2. TECHNICAL CHARACTERISTICS

- Track length: 120cm
- Overall straightness: <0.10mm
- 400mm straightness: <0.05mm
- Working plane angle: 90° ±0.1°
- Surface roughness: Ra 3.2
- Diameter of air holes: 0.8mm
- Air feed fitting diameter: 30mm
- Working air pressure: >5.8kPa
- Operating conditions: 0°C to +40°C, RH <85%
- Glider length: 121mm
- Glider mass: ~155g
- Operating air gap: >0.10mm (glider loaded <465g, air pressure >5.8kPa)

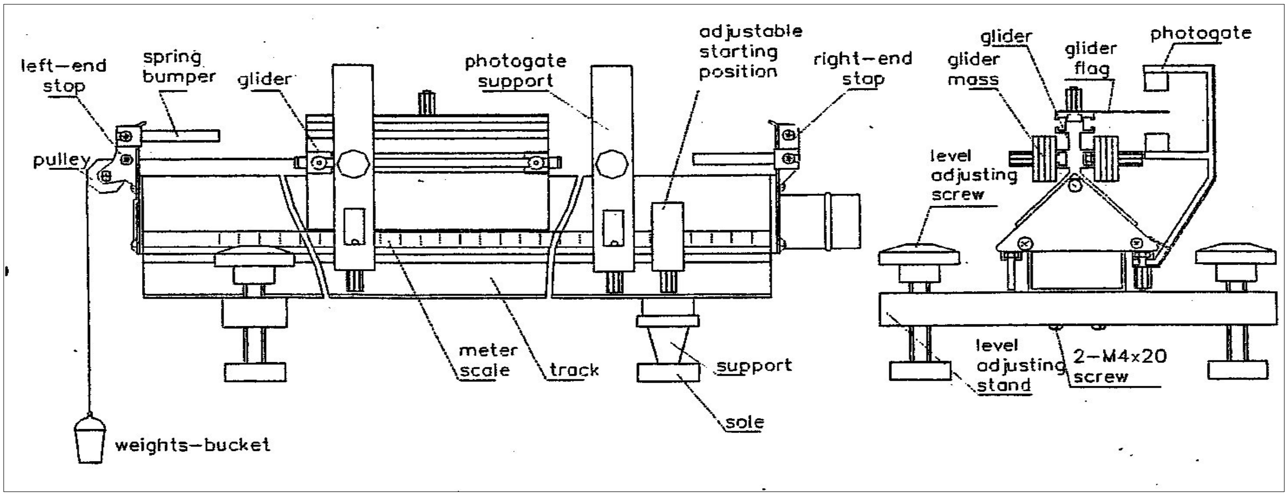

Figure 1.1: Assembled Apparatus

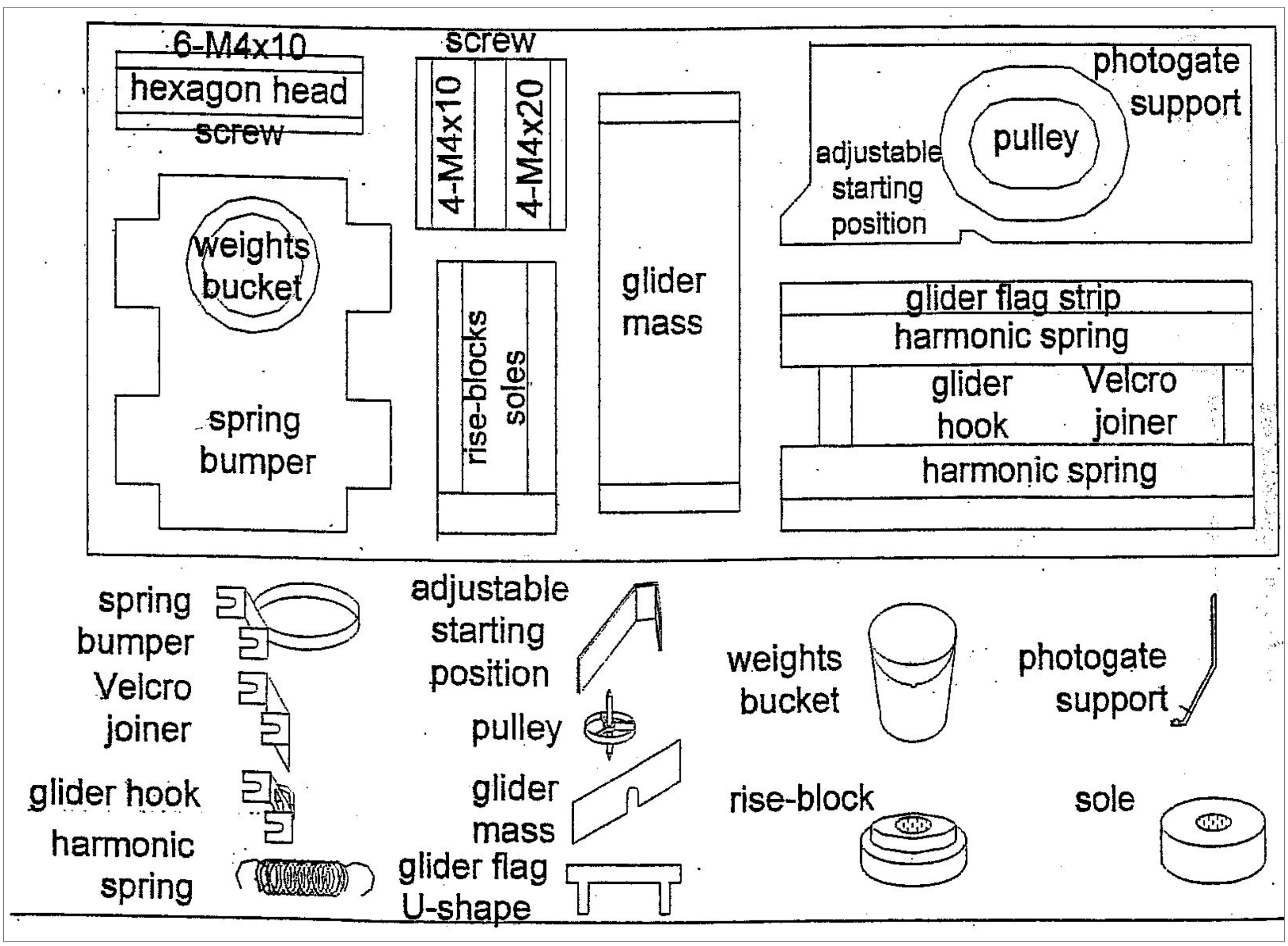

Figure 1.2: Accessories in Storage Tray

3. OPERATION AND MAINTENANCE

A wide variety of experiments may be performed with the air track. The air track set includes an array of accessories to support these experiments. It is recommended that this manual be read thoroughly to gain familiarity with the track and its accessories, so that the full flexibility of the set may be realized.

3.1 Assemble the level adjusting stand to the bottom of the track with two M40-20 machine screws and bolts. Place the accessory plastic soles under the feet of the apparatus, so that the tips of the feet rest in the center holes of the soles. Position the air track on a flat, level, hard surface. Use a spirit level to adjust the leveling screws on the level-adjusting stand so that the stand is horizontal. Inclination of the track may be adjusted by placing a rise block under the single support. Inclination can be fine-adjusted by partially unscrewing the single support; the screw pitch on the support is 1mm. Leave the apparatus in place for the duration of the session; it will have to be re–leveled if it is moved.

3.2 Attach the flexible air hose between the air feed fitting and the blower / air supply. Turn on the air supply and verify that all holes on the track are clear. If a hole is obstructed, it may be cleared with a 0.5mm pin or wire. The rubber end caps of the track can be removed to clean the inside of the track as necessary.

3.3 To level the air track: With the air supply turned on, place a glider on the track. Release the glider gently so that your hand does not impart even a slight force to the glider once it is floating on its air cushion. Verify that the glider remains stationary on the track, not drifting to one side or the other. If the glider drifts, adjust the height of the single track support by screwing or unscrewing the support.

3.4 Optimum glider speed is ~50cm/s. Best results will be obtained if experimental conditions result in glider speeds in this vicinity.

3.5 To avoid influencing the motion of the glider, care must be exercised that the track and glider are not touched, jarred, or otherwise interfered with while the glider is in motion. Also, to avoid marring the surface of the track, never place a glider on the track, or let a glider rest on the track, unless the air supply is turned on.

3.6 After each session, the track surface should be wiped gently with a clean, dry, soft, lint-free cloth. The track should be stored **hanging vertically**, in a cool, dry location.

4. EXPERIMENTS

4.1 Average and Instantaneous Velocity

Velocity may defined as distance traversed divided by time taken to traverse that distance, or $v = \Delta s / \Delta t$. If Δs is finite, v as defined will be the average velocity over that distance. As the time Δt approaches zero, v approaches the instantaneous velocity at s; in other words, $v = \lim_{\Delta t \to 0} (\Delta s / \Delta t)$. In this experiment, an accelerated motion will be set up. Average velocity will then be determined from a fixed point over a series of successively shorter Δs, hence, shorter Δt. Average velocity will be seen to approach an instantaneous velocity as Δt is decreased.

Step 1: Set up the apparatus as shown in Figure 4.1. Level the track as described in paragraph 3.3. Incline the track by placing the short rise block under the single support. Install the starting position bracket at a convenient position on the high end of the track, and a spring bumper on the low end. Install one photogate at about the 70cm position.

Step 2: Turn on the air supply. Put the timer in the “S2” mode.

Step 3: Install a 10cm U-flag on the glider. Place the glider on the high end of the track, in contact with the starting position bracket.

Step 4: Release the glider gently but sharply. The glider will accelerate down the track, pass the photogate, and rebound off the spring bumper.

Step 5: Press the [Memory] button on the counter. Record time “C1”.

Step 6: Repeat steps 3 through 5 with the 5cm, 3cm, and 1cm U-flags on the glider, recording the time “C1” corresponding to each U-flag.

Step 7: Calculate $v = \Delta s / \Delta t$ for each flag, using the distance between flag leading edges as Δs, and the corresponding C1 as Δt.

Step 8: Observe that v approaches an instantaneous value as Δs decreases. You may wish to plot v as a function of Δs.

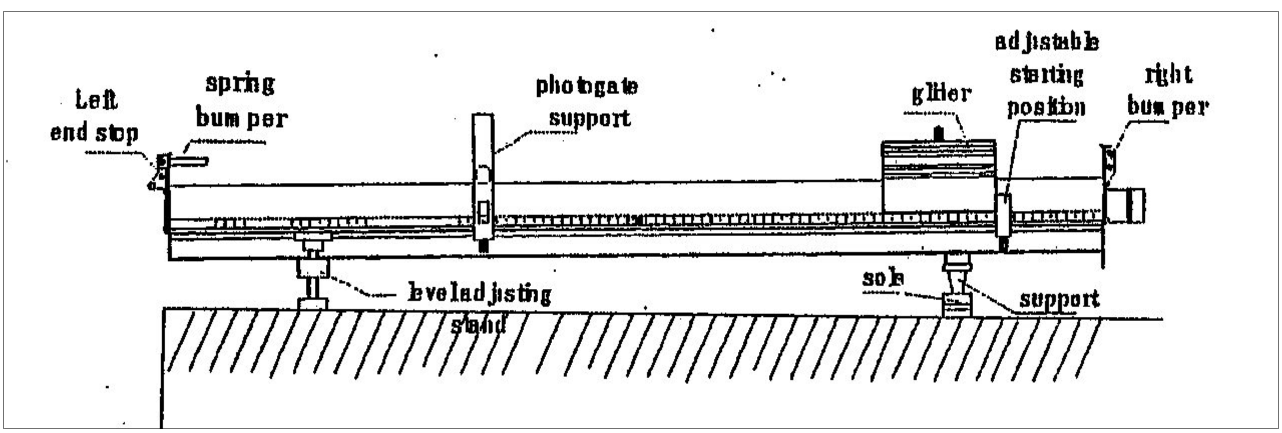

Figure 4.1: Velocity

4.2 Acceleration

Acceleration is defined as the time rate change of velocity, or $a = (v_2 - v_1)/t_{1-2}$, where v_1 and v_2 are the instantaneous velocities corresponding to times t_1 and t_2, and t_{1-2} is the time elapsed between t_1 and t_2. In this experiment, an accelerated motion will be set up. Velocities will be determined at two well-separated photogate positions; as well the time elapsed between photogate passings. From these data, acceleration can be calculated.

Step 1: Set up the apparatus as shown in Figure 4.2. Level the track as described in paragraph 3.3. Incline the track by placing the short rise block under the single support. Install the starting position bracket at a convenient position on the high end of the track, and a spring bumper on the low end. Install two photogate at about the 30cm and 90cm positions.

Step 2: Turn on the air supply. Put the timer in the "a" mode.

Step 3: Install a 1cm U-flag on the glider. Place the glider on the high end of the track, in contact with the starting position bracket.

Step 4: Release the glider gently but sharply. The glider will accelerate down the track, pass the photogates, and rebound off the spring bumper.

Step 5: Record times "1", "1 – 2", and "2" from the timer.

Step 6: Calculate $v_1 = \Delta s/\Delta t_1$, using 1cm (the distance between flag leading edges) as Δs, and the time "1" as Δt_1. Calculate v_2 similarly.

Step 7: Calculate acceleration as $a = (v_2 - v_1)/t_{1-2}$. You may wish to repeat the experiment a number of times to evaluate average deviation and possible error.

Step 8: Optional. The short rise block is 5mm tall, and the distance between track supports is 600mm. This gives the track a slope of $5/600 = .0083$. You may wish to verify that the acceleration of the glider equals the acceleration of gravity ($a = 980\,cm/s^2$) times the slope of the track.

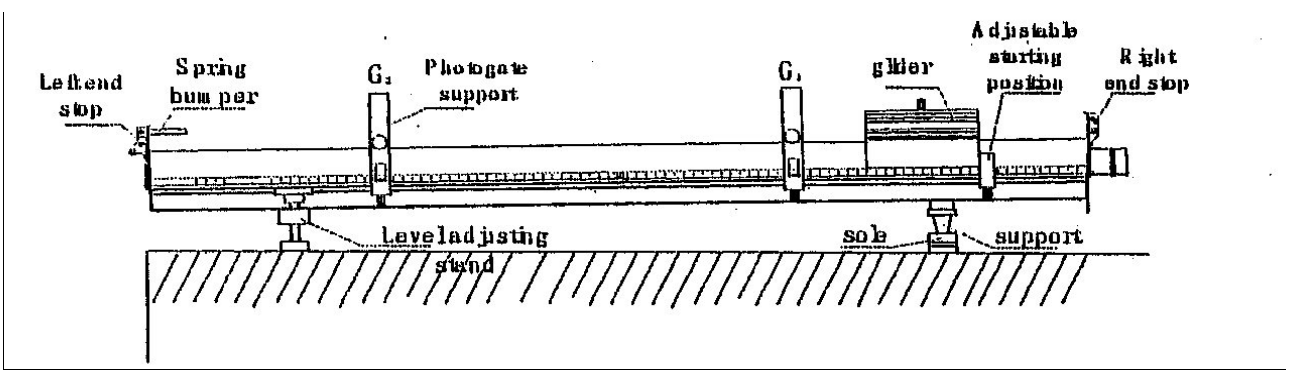

Figure 4.2: Acceleration

4.3 Newton's Second Law of Motion

Newton's Second Law states the equivalence of force with the time rate change of momentum. This is equivalently expressed as mass times acceleration, or $f = m \cdot a$. In this experiment, the track will be level, but the glider will be accelerated by a constant force. This force will be the weight of a hanging weight bucket, attached to the glider by a cord passing over a pulley. The acceleration of the glider will be equal to the hanging weight, divided by the combined masses of the glider and hanging weight.

The experiment can be performed either by holding glider mass constant and varying the hanging weight, or by holding hanging weight constant and varying the glider mass. Both methods are described below.

4.3.1 Method 1: Constant Glider Mass, Varying Hanging Weight

Step 1: Set up the apparatus as shown in Figure 4.3. Position the track so that the end opposite the air supply extends slightly beyond the edge of the table. Level the track as described in paragraph 3.3. Install the starting position bracket at a convenient position at the air-supply end stop. Install a spring bumper on the bracket on the opposite end stop. Install two photogates at about the 30cm and 90cm positions.

Step 2: Install the pulley between the two bearing screws on the end stop opposite the air supply. Run the bearing screws in far enough that they hold the needle bearings of the pulley captive, but that the pulley spins freely. Apply a drop of light oil to each bearing.

Step 3. Install a 1cm U-flag and a glider hook on the glider. Weigh the glider and the empty weight pail on a beam scale. Record these weights.

Step 4: Run a length of light cord over the pulley. Secure the hanging end to the weight pail, and the other end to the glider using a glider hook. Adjust the length of the cord and the position of the starting position bracket, such that the pail does not touch the floor with the glider at the pulley end of the track, and so the pail does not climb over the pulley with the glider at the starting bracket.

Step 5: Turn on the air supply. Put the timer in the “a” mode.

Step 6: Place the glider at the end of the track, in contact with the starting position bracket. Verify that the cord is in the sheave of the pulley. Make the initial run with an empty pail.

Step 7: Release the glider gently but sharply. The glider will accelerate down the track, pass the photogates, and rebound off the spring bumper.

Step 8: Record times “1”, “1 – 2”, and “2” from the timer.

Step 9: Calculate $v_1 = \Delta s / \Delta t_1$, using 1cm (the distance between flag leading edges) as Δs, and the time “1” as Δt_1. Calculate v_2 similarly.

Step 10: Calculate acceleration as $a = (v_2 - v_1)/t_{1-2}$. You may wish to repeat the experiment a number of times to evaluate average deviation and possible error.

Step 11: Add about 5g to the pail, press the [Clear] button on the timer, and repeat steps 6 through 10. Repeat with 10g added to the pail.

Step 12: Verify that for each case, acceleration of the glider is equal to the weight of the pail, divided by the combined masses of the glider and pail.

4.3.2 Method 2: Constant Hanging Weight, Varying Glider Mass

Step 1: Set up the apparatus per steps 1 through 5 of paragraph 4.3.1 above. Put 10g in the pail.

Step 2: Place the glider at the end of the track, in contact with the starting position bracket. Verify that the cord is in the sheave of the pulley. Make the initial run with an unweighted glider.

Step 3: Release the glider gently but sharply. The glider will accelerate down the track, pass the photogates, and rebound off the spring bumper.

Step 4: Record times “1”, “1 – 2”, and “2” from the timer.

Step 5: Calculate $v_1 = \Delta s / \Delta t_1$, using 1cm (the distance between flag leading edges) as Δs, and the time “1” as Δt_1. Calculate v_2 similarly.

Step 6: Calculate acceleration as $a = (v_2 - v_1)/t_{1-2}$. You may wish to repeat the experiment a number of times to evaluate average deviation and possible error.

Step 7: Add a 50g weight to the glider, press the [Clear] button on the timer, and repeat steps 2 through 6. Repeat with 100g added to the glider.

Step 8: Verify that for each case, acceleration of the glider is equal to the weight of the pail, divided by the combined masses of the glider and pail.

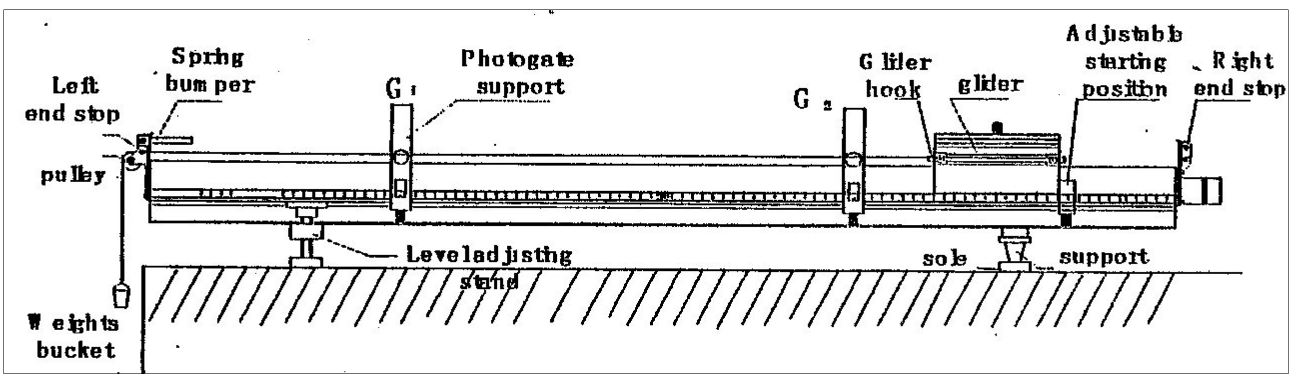

Figure 4.3: Newton's Second Law of Motion

4.4 Conservation of Momentum

Momentum is defined as the product of mass and velocity. The total momentum of a system remains constant (or is *conserved*) through any lossless process. In these experiments, the momentum of two gliders is determined before and after impact. Two photogates are mounted at fixed positions along the test track. The gliders are fitted with double flags of known distance between leading edges. The gliders are then placed on the track, outside the photogates, and put in motion toward each other so that they collide between the two photogates. Interval time is measured at each photogate passing. The velocity at either photogate may be calculated by the formula $v_n = d_{flag} / t_n$.

Both elastic and inelastic collision can be investigated. In the case of elastic collision, the gliders rebound off each other at impact, exchanging momentum according to $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$. In the case of inelastic collision, the gliders remain coupled at impact and combine momentum according to $m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$.

4.4.1 Elastic Collision

Step 1: Set up the apparatus as shown in Figure 4.4.1. Level the track as described in paragraph 3.3. Install spring bumpers at both ends of the track. Install two photogate at about the 30cm and 90cm positions.

Step 2: Install 1cm U-flags on the gliders. Install a spring bumper on one of the gliders. Weigh the gliders on a beam scale. Record these masses.

Step 3: Turn on the air supply. Put the timer in the "Col" mode.

Step 4: Place the gliders at their initial positions outside the photogates. Place the glider with the spring bumper on the track so that the bumper faces the other glider.

Step 5: Set both gliders into motion toward each other. The gliders pass their respective photogates, collide, and make final photogate passes. Interval times for each photogate will be displayed on the timer.

Step 6: Calculate initial and final velocities for each glider by the formula $v = \Delta s / \Delta t$, using 1cm (the flag leading edge distance) as Δs, and interval times as Δt.

Step 7: Calculate the total momentum of both gliders, before and after collision. Total momentum before collision should equal total momentum after collision according to $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$.

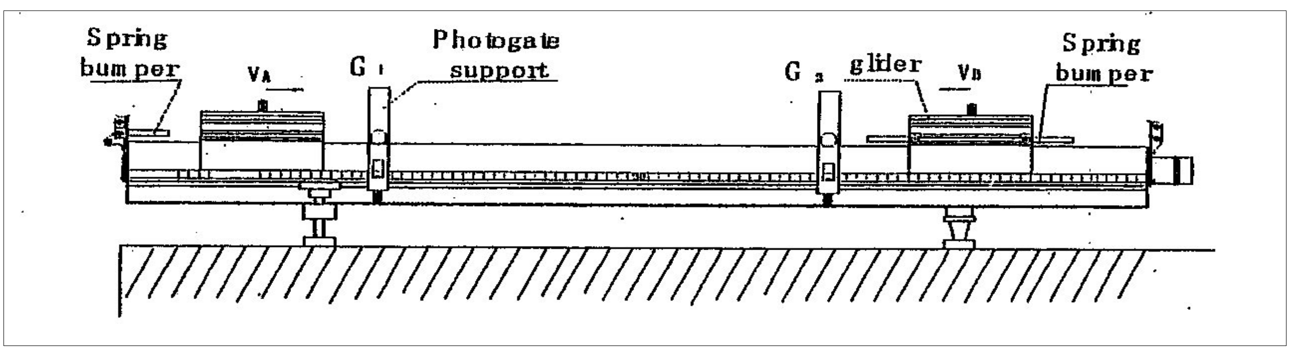

Figure 4.4.1: Elastic Collision

4.4.2 Inelastic Collision

Step 1: Set up the apparatus as shown in Figure 4.4.2. Level the track as described in paragraph 3.3. Install spring bumpers at both ends of the track. Install two photogate at about the 30cm and 90cm positions.

Step 2: Install 1cm U-flags on the gliders. Install a velcro joiner on each of the gliders. Weigh the gliders on a beam scale. Record these masses.

Step 3: Turn on the air supply. Put the timer in the "Col" mode.

Step 4: Place the gliders at their initial positions outside the photogates. Place the gliders on the track so that the velcro joiners face each other.

Step 5: Set both gliders into motion toward each other. The gliders pass their respective photogates, collide, and make final photogate passes. Interval times for each photogate will be displayed on the timer.

Step 6: Calculate initial and final velocities for each glider by the formula $v = \Delta s / \Delta t$, using 1cm (the flag leading edge distance) as Δs, and interval times as Δt.

Step 7: Calculate the total momentum of both gliders, before and after collision. Total momentum before collision should equal total momentum after collision according to $m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$.

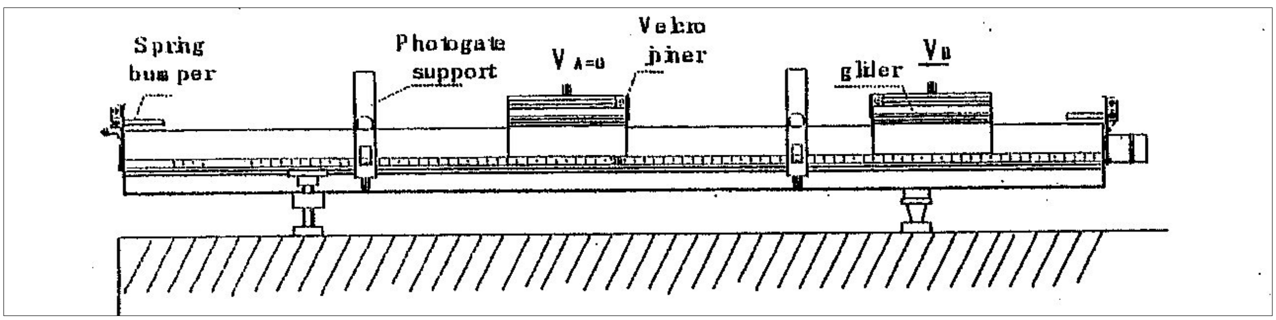

Figure 4.4.2: Inelastic Collision

4.5 Simple Harmonic Motion

A mass constrained by a linear spring, set in motion about its equilibrium position, will exhibit simple harmonic motion. The period of vibration is given by the equation $T = 2\pi\sqrt{m/K}$, where m is mass, and K is the spring stiffness.

In this experiment, a glider will be attached between two springs, which in turn are attached to the air track end stops. The glider oscillates, with a single flag passing through a photogate as it passes its equilibrium position.

Step 1: Set up the apparatus as shown in Figure 4.5. Level the track as described in paragraph 3.3. Install a spring on each of the end stop brackets. Install a photogate at the 60cm position.

Step 2: Install a single flag and two glider hooks on the glider. Weigh the glider on a beam scale. Record this mass.

Step 3. Turn on the air supply. Put the timer in the "T" mode.

Step 4: Connect the glider hooks to the free ends of the two springs.

Step 5: Place the glider on the track, about 30cm to one side of the photogate. Release the glider gently but sharply. The glider will oscillate about the photogate.

Step 6: After several cycles, record the period times from the timer. Average these times.

Step 7: Calculate the ratio $T/\sqrt{m}$.

Step 8: Attach one 50g weight to the glider. Repeat steps 2 through 7. Verify that the ratio $T/\sqrt{m}$ is equal to that previously calculated in step 7.

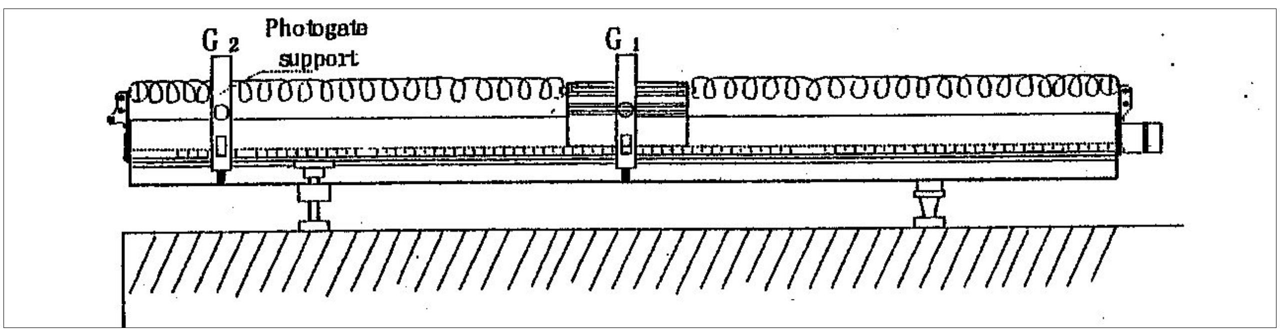

Figure 4.5: Simple Harmonic Motion