Lab Skills: Introduction to the Air Track*

1 What is an air track?

An air track is an experimental apparatus that allows the study of motion with minimal interference by frictional forces. It consist of a track with many small holes through which air is blown continuously. Gliders are placed on top of the track, but do not contact it, since the flow of air causes them to hover just slightly off of the track. By allowing the air track gliders to move on a cushion of air, frictional effects are reduced.

A blower adjusted to the correct output level forces air inside a piece of aluminum extrusion. The high air pressure inside the track forces air out of the track through small holes drilled into the upper surface of the track. The air track glider rides on this surface of air.

To make effective use of eliminating friction from our experiments we need to measure speeds with great accuracy. This is accomplished with the use of "photogates". Combined with these sophisticated timing devices, low friction air tracks enable the experimenter to make high accuracy confirmations of fundamental motion studies.

Before you start experimenting with the air track, you must learn how to avoid damaging them. The tracks are made of aluminum which is a soft metal and **easily scratched, nicked, bent, and damaged** if not handled carefully. Any irregularity in the track surface will increase frictional effects and reduce the accuracy of your results. Please be considerate of our equipment, take care not to damage these tracks as they are expensive and must last the De Anza physics department a long time.

2 How to avoid damaging the air tracks

1. Never place a glider on a track unless there is air blowing out through the track's holes. Never slide a glider along the track unless there is air blowing out through the small air track holes. Before putting the glider on the track, feel the air blowing out of the track with your hand. The glider must slide on a layer of air and must never slide touching the aluminum track. Contact between the glider and track will scratch and ruin the track's surface.

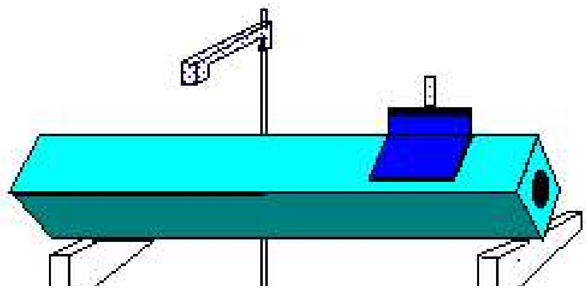
2. Remove and replace the track from the storage rack slowly with great care making sure the track does not collide with other objects. **The track is long. Removing and replacing it is a two person procedure where each person is in charge of one end of the track to ensure it hits nothing.** Hitting the track will throw it out of alignment. These tracks are straight to within 0.02 millimeters over their entire length. Deviations from this tolerance will reduce the accuracy of your results.

*These notes are by Prof. Newton with small modifications.

3. Never put any kind of tape on the track or glider. Do not write on the glider with pen or pencil. It is also a good idea not to excessively touch the track with your hands since finger oil will eventually gum up the track's surface.

4. **Never push down on a glider.** On or off the air track, pushing downward on a glider may bend the delicate sides of the glider. The angle between the sides of the glider must match the ninety degree angle of the track surface.

3 Preparing the air track, gliders, and photogates for an experiment



3.1 Preparing the air track

1. Carefully remove the air track from its cradle on the storage cart and place it on your lab bench. This is a two person job!

2. You will also need the following items:

   - one air blower box
   - one blower box power cord
   - one flexible air hose
   - two "end pieces" for each end of the track one flat plastic accessory box

3. Connect the air blower hose to the track and the blower; connect the power cord to the blower. Turn on the blower to a level of about **2 units** to allow the track to warm up. (Once it has warmed up, you will turn it up further before putting a glider on the track.)

4. In the accessory box you will find four thumb screws used to mount the two end pieces on the air track. Mount the end pieces on the track. Remember these must be taken off when you are done.

5. Also from the accessory box, remove two end reflectors (they are flat and U-shaped) and insert a rubber band tautly in each one. Insert each end reflector in the end piece you already mounted on the air track. Insert the end reflector in the top hole of the end piece.

3.2 Preparing the glider

The plastic box has many items for the glider. These items can be added to one side or the other of the glider or the top of the glider. There are also weights provided to increase the mass of your glider. For the correct balance, weights should always be added evenly to both sides of the glider. Your lab experiment equipment list will tell you exactly what accessories are needed for a given lab. You always need at least one glider (see your experiment equipment list) and the accessory box.

You will always need an accessory in the top of the glider to act as a “flag” (see below, section 6). The flag triggers the photogate. Typically the flag will be one of the cylindrical plugs found in the accessory box. You will also need an accessory inserted into both ends of the glider. Often this will be a cylindrical plug with a flat end on it (two of these are in one accessory box). Insert one of these cylindrical plugs with a flat end in each end of the glider. Use the upper of the two holes in the glider end to insert the cylindrical plug. The flat end on the glider should be oriented vertically so that it will push against the rubber-band reflector on the end of the air track.

You are asked to hold the glider in your hand when adding accessories to it and not add accessories while the glider is on the lab bench, or the air track, to prevent having the sides of the glider bent from pushing down on it while it rests on a hard surface. Your hand holding the glider will “give” when pushing an accessory into the glider and therefore the sides of the glider will not be bent or damaged.

3.3 Preparing the photogate timers

You will need at least one photogate timer (see your experiment equipment list). You will also need a power cord for the photogate. The power cord will have a transformer end that plugs into the power outlet; you may also need an adaptor to plug the transformer into the lab bench power strips. The photogate timer is turned on by turning the slide switch to gate, pulse, or pendulum mode. To correctly position the photogate see sections 4 and 5 below.

Note: When finished with your experiment, the process for disassembling the apparatus is the reverse of the above. Make sure you take the glider off the track before you turn off the air blower.

4 How to adjust the air track and photogates for optimum accuracy in measurements

1. Photogate placement. For accurate results the photogates must be correctly placed. See Figure 1 and notice how close one side of the photogate is to the glider. This eliminates so-called parallax error. The glider has a “flag” that triggers the timer.

   A flag is an object placed on the top of the glider that interrupts the photogate beam and activates the timer. Use a cylindrical plug on the top of your glider as a flag. Using the cylindrical plug means that the cross sectional length the beam senses is independent of the rotation of the cylinder. This is important so you don’t have to worry about the rotational position of the flag affecting your measurements.

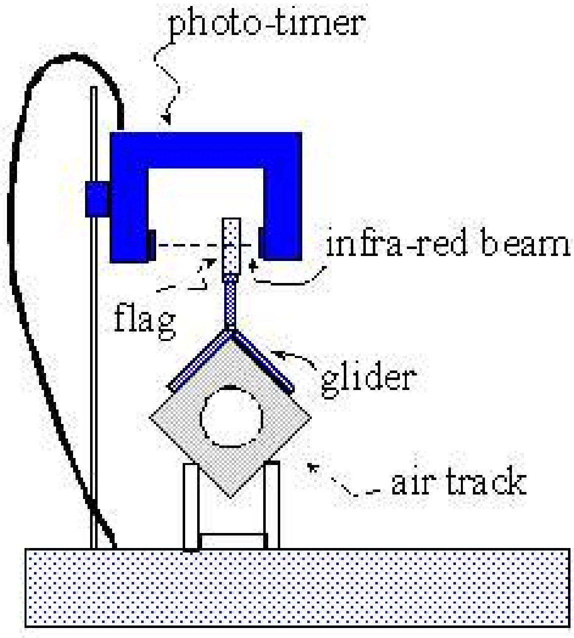


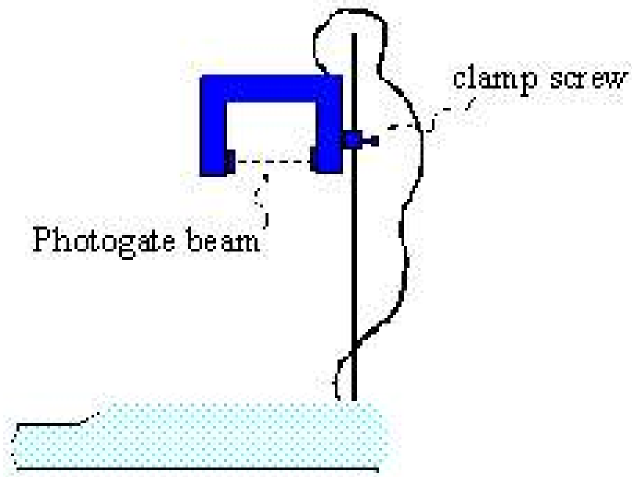
Figure 1: End view of track with aligned photogate.

2. Blower output level. The blower output may be too low or too high. If the blower output level is too low then the glider may scrape the track and damage could result. If the blower output level is too high, the glider may be blown one way or the other and your results will be less accurate. It is better to have the blower output too high than too low! Note that the air output through the small holes is higher near the blower input end of the track and air output is lower at the end of the track far from the blower input. Make sure air output is high enough to keep the glider from scraping the track at the end of the track farthest away from the blower input. **A blower output level of at least 2.5 is correct when one unweighted glider is on the track.** You will have to increase the output level when two gliders are used or when a more massive glider is on the track. As long as a glider does not noticeably slow down from a gentle push, the output level is high enough.

3. How to level the air track. Unless your experiment involves tilting the track for an inclined plane experiment, you must make sure your track is level. Place one glider near the center of the track. If the track is level, the glider will drift back and forth randomly but will not pick up much speed traveling either to the left or to the right. Placed at rest on the track it *should* remain at rest. The track is leveled at one end only using the adjusting screws found on its long “foot”. Leveling may take time, be patient.

5 Understanding the photogate timer

A narrow infra-red beam is emitted from the arm close to the vertical positioning pole. This beam strikes a detector in the opposite end of the arm away from the vertical positioning pole. A timer circuit is connected to the detector that allows four types of timing modes to be used. When the beam is blocked a red LED (Light Emitting Diode) lights up on the top of the photogate arm.



Be careful not to over tighten the clamp screws on the photogate arm and notice the small metal lever switch (the memory switch) on the photogate timer cannot be turned in the left and right direction but up and down only.

The four timing modes:

1. **Gate Mode:** Use this mode to calculate speeds. The timer is activated when the beam is blocked. When the beam is unblocked the timer switches off. If you know the length, L, of an object (e.g. your glider's flag) and the time it takes for the object to go through the photogate then you can compute the average speed of the object as it passes through the photogate. Note, in reality you must not use the "physical" length of the object but the so-called "effective" length, L_{eff}, of the object. See the effective length section found below for more details.

2. **Pulse Mode:** Use this mode to calculate the time one object moves between two different photogates placed some distance apart (a second accessory photogate is necessary). Timing begins when the beam is first blocked and continues after the beam is unblocked; timing terminates when the beam is blocked again a second time at the second photogate.

3. **Pendulum Mode:** Use this mode to calculate the period of one full oscillation. The timer starts when the beam is first interrupted and the timer continues through one more interruption and then finally stops on the third interruption.

4. **Manual Stopwatch:** In Pulse mode the START/STOP button makes the timer act as a conventional stopwatch. In Gate mode the timer starts when the START/STOP button is pressed and the timer stops as soon as the button is released.

The switches:

Memory switch: Each timer has a memory switch to allow the recall of a previously timed value. When you recall the stored time, the time displayed is the sum of both events.

Therefore you must subtract the two displayed times to find the time of the stored event. Typically, leave the memory switch in the "off" position.

Resolution switch: The slide switch on the front panel enables the user to set the "resolution" of the timer to 1 ms (ms $= 10^{-3}$ seconds) or to 0.1 ms. In both cases the timer is accurate to 1 percent of its readout. The difference between the two settings is that on the 1 mS setting a maximum time interval of 20 seconds can be measured whereas on the 0.1 ms setting only a time interval of 2 seconds can be measured. Not remembering this can lead to many frustrating measurement errors. Unless otherwise told, leave the switch on the 1 ms setting.

6 Finding the effective length of the flag and calculating its speed

Although it sounds odd, the physical length of the flag you use on the glider is not exactly equal to the length that the beam senses with the photogate! The length the beam senses is called the "effective length", L_{eff}, and can be measured with the following procedure.

1. With the glider off the track and held in your hand, gently place a cylinder into the top of the glider. This cylinder is your flag. Remember, don't push down hard on the glider or you may bend its sides.

2. Make sure the blower is turned on so the glider does not touch the track when placed on it.

3. Place the glider on the track near a photogate timer switched to GATE mode. Make sure the photogate is correctly positioned as described above in section 4.

4. Adjust the vertical height of the photogate so only the cylinder on the glider will trigger the photogate. Move the glider in and out of the photogate. See that as soon as the flag on your glider blocks the photogate the red LED on the top of the photogate arm lights up. Use this red LED as the indicator of when the flag first blocks the photogate.

5. You are now ready to measure the effective length of the flag. Make sure the timer is not running. Slowly move the glider into the photogate until the red LED goes on. Record in your lab book the position the front edge of the glider makes with the ruler on the track just when the glider triggers the photogate. Continue to move the glider through the photogate until the red LED goes off. When the red LED shuts off, record the new position of the glider's front edge with respect to the air track's ruler. The difference between your two recorded positions is the effective length of your flag, L_{eff}; the value should be about 1 cm, you should have the value to one decimal place. Make sure this length is clearly recorded in your lab book. All speed calculations are made using this length.

6. Calculating the speed of a glider in an experiment. Now that you know the effective length of the flag, you can calculate the average speed of the glider as it moves through the photogate by dividing the effective length of the flag, L_{eff}, by the time the flag keeps the timer activated, Δt.

$$v_{\text{glider}} = \frac{L_{\text{eff}}}{\Delta t}$$