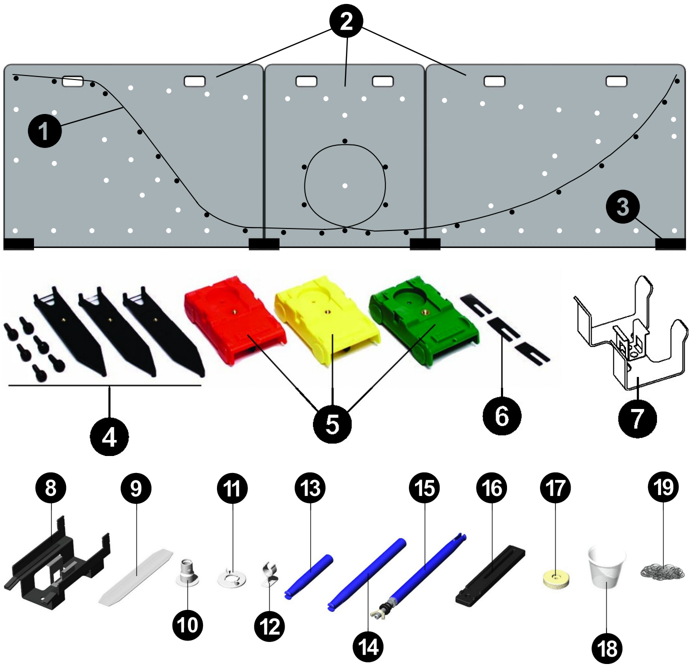
Roller Coaster (ME-9812)

Introduction

The PASCO Roller Coaster includes loops and hills for studying conservation of energy and centripetal acceleration, a straight track for studying collisions, and a brachistochrone for demonstrating the path of least time.

Equipment list



1 Roller coaster track (1 coil)
Has a total length of 9.1 m and a width of 5.1 cm.

2 Support panels
Left and right panels measure 85.9 cm x 60.4 cm. Middle panel measures 52.8 cm x 60.4 cm.

3 Support feet (4×)
Use to keep the freely standing support panels upright.

4 Collision accessory with 6-32 screws (3×)
Use to create elastic or inelastic bumpers for mini-cars, as well as to connect cars together.

5 Mini-Cars (ME-9813) (3×)
Includes one red, one yellow, and one green car, each with a mass of 0.18 kg.

6 Flags for Mini-Cars (3×)
Attach to the mini-cars to trigger photogates.

7 Mini-Car Starter Bracket (2×)
Insert mini-car into bracket to prevent it from rolling down the track until released.

8 Catchers (2×)
Use to create a bumper to catch or bounce a mini-car at the end of a track segment.

9 Track couplers (2×)
Connect two sections of track by sliding a coupler halfway into the slot on the underside of the track.

10 Hole inserts (70×)
Place one into each hole in the support panels to hold pegs and other components.

11 Hole insert nuts (70×)
Use to secure the hole inserts in position.

12 Peg clips (50×)
Attach to holes in the underside of the track to attach the track to pegs.

13 Short pegs (3×)
7.4 cm length.

14 Long pegs (40×)
16.2 cm length.

15 Photogate mounting pegs (4×)
18.9 cm length. Use to hold a photogate in position over the track.

16 Photogate brackets (4×)
Use to adjust the height of the photogate above the track as needed.

17 Ballast masses for Mini-Cars (3×)
Each has a mass of 0.04 kg.

18 Water cups (3×)

19 Rubber bands
Both lengths of rubber bands are contained in a single package.

20 Claytoon clay (not pictured)
Used to create an inelastic bumper for the Mini-Cars in completely inelastic collisions.

Recommended equipment:

Photogates can be used with the Roller Coaster to measure the speed of the mini-cars on the track. Recommended options for photogate timing include:

- Wireless Smart Gate (PS-3225) with PASCO Capstone or SPARKvue data collection software
- Smart Timer Photogate System (ME-8932)

Track assembly

Plugging in the hole inserts

To prepare the Roller Coaster for first use, the hole inserts must be plugged into the holes. This is a **one-time installation**, as the inserts are a permanent part of the support panels.

1. To install the inserts, press one plastic insert into each of the 70 holes in the three boards. The inserts should be inserted from the white side of the panel, as shown in Figure 1.

> **NOTE:** There is a notch on the inside of the inserts, which allows the photogate pegs to be keyed into the insert to prevent rotation. Orienting each insert with the notch at the bottom makes it easier to locate the notch when a photogate peg is used.

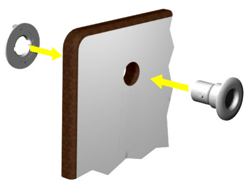


Figure 1: Pressing an insert into the support panel.

2. On the back side of each board, secure each insert with an insert nut by twisting the nut onto the insert by hand, as seen in Figure 2.

Figure 2: Tightening the nut on the insert.

3. Place the provided board labels on each board to identify the left, center, and right panel boards.

Using support feet with the support panels

There are many different track configurations possible with the support panels, with several examples shown in the **Suggested experiments** section. Some configurations use two support panels, while others use all three. The support panels can be used in different orientations if required.

The panels are supported in the vertical position by placing them end-to-end in the slots of the black support feet. When all three support panels are used, four support feet are required: one on the left end of the left board, one on the right end of the right board, one spanning the junction of the left and center boards, and one spanning the junction between the center and right boards. If only two panels are used together, only three support feet are required. By default, the panels are not connect to each other in any other way. However, if desired, a large binder clip can be used to clip the joints together at the top of the boards.

Attaching the track to the support board

The 9.1 m track is shipped in a coil. Before first use, it may be necessary to lay the track out flat for a few minutes to remove any set. We recommend cutting this track into sections. A length of approximately 4 m is required for the roller coaster loop. If the track length exceeds the amount for the required for the selected track configuration, allow the excess track to hang off one end.

1. Select the desired track configuration. Push a peg into each of the holes along this configuration until they snap into place. Pegs can be removed by pulling firmly with your hand.
2. Begin connecting the track to each of the pegs, starting at one end and moving along the planned track route. To connect the track to a peg:
    a. Place a peg clip into a slot on the underside of the track at the location of the peg.
    b. Twist the peg clips in the slot so the edges of the slot capture the clip (see Figure 3).
    c. If needed, slide the clip in the slot a short distance to align it with the peg.
    d. Snap the clip into the peg.

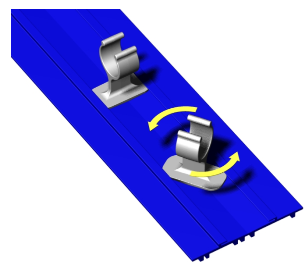


Figure 3: Snapping the clip onto the peg.

Two different lengths of pegs are supplied. Long pegs are required for running two tracks side-by-side. Short pegs are occasionally required to avoid collision between the peg and the car on a second track.

Track configurations are shown in the **Suggested experiments** section. If needed, shorter sections of track can be connected using a track coupler, which is a metal strip that slides into the slot on the underside of the track. Slide the coupler halfway into the end of each track section to join the two sections together.

Attaching photogates to the track

The Roller Coaster kit includes special pegs with threaded rods on one end. These pegs are used to mount photogates to the board.

1. Wherever a photogate is needed along the track, replace the regular peg with a special photogate peg. Align the pin on the photogate peg with the notch in the board insert.
2. Attach the photogate to the photogate bracket.
3. Remove the wing nut from the threaded peg and slide the photogate bracket onto the threaded peg (see Figure 4).
4. Use the thumb nut on the threaded peg to change the distance of the photogate from the board.
5. Once the photogate is as the desired distance from the board, secure it in place with the wing nut.

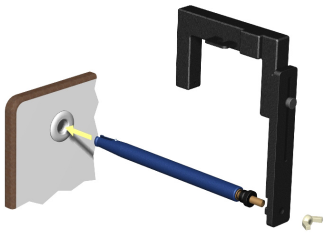


Figure 4: Mounting the Photogate Head (ME-9498A) to the support panel.

The track position can be adjusted to be closer or farther from the board to ensure the car flag passes through the photogate.

Attaching the catcher to the track

The catcher has multiple possible uses:

- It can be positioned anywhere on the track to catch the car and prevent it from rolling back down an incline.
- It can be used as an elastic bumper so the car bounces back and returns down the track.
- It serves as a mounting place for the Super Pulley with Clamp (ME-9448B) when attaching a string to a hanging mass over a pulley.
- It can be used as a catcher on the Rotating Platform (ME-8951) to perform a conservation of angular momentum experiment. In this case, the car goes off the end of the track and into the catcher, causing the platform to rotate.

To attach the catcher to the track, squeeze the spring clip, insert the clip into the slot on the bottom of the track, and release the clip. (See Figure 5.)

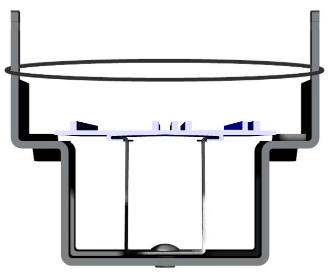


Figure 5: Attaching the catcher to the track (end view) with rubber band bumper.

To create a rubber band bumper, stretch a rubber band across the two posts that stick up from the catcher. If you want the catcher to catch the car, orient the catcher so that the car enters the end of the catcher opposite the rubber band bumper. If you want the car to bounce off, orient the catcher so the car hits the rubber band bumper.

The catcher can be placed anywhere on the track. It can be placed between adjacent pegs, or a peg can be inserted through the center hole of the catcher on either side of the spring clip. When using a clamp-on pulley, insert a peg through the catcher as shown in Figure 6 so the peg doesn't interfere with the pulley. The pulley clamps onto the lower section of the catcher.

NOTE: Do not clamp pulleys directly to the track, as this will cause the track to deform.

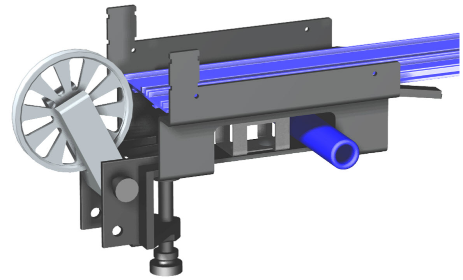


Figure 6: Clamping the pulley to the catcher.

Attaching the starter bracket to the track

The starter bracket's main purpose is to help align the mini-car when it is placed on top of the track. To attach the starter bracket to the track, squeeze the spring clip, insert the clip into the slot on the bottom of the track, and release the clip. (See Figure 7.)

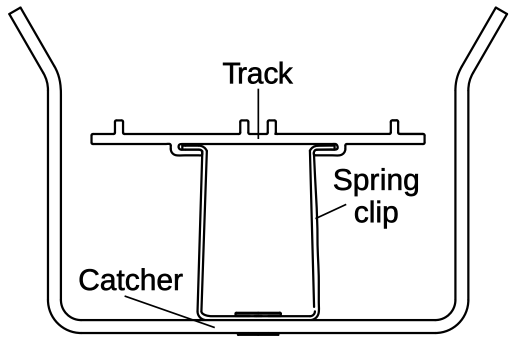


Figure 7: Attaching the starter bracket to the track (end view).

Place the mini-car between the sides of the starter bracket, making sure to align the wheels with the grooves on the track. (See Figure 8.)

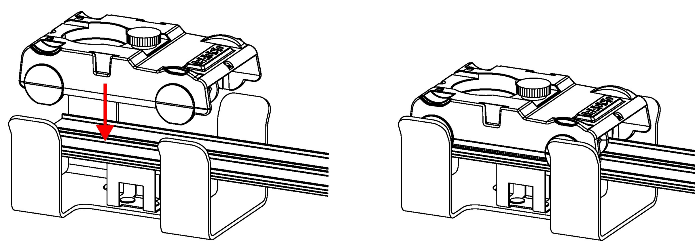


Figure 8: Placing the mini-car onto the track.

Using the track without a support board

The track can be used without the support board. It can be laid out flat on the table or floor or taped to a board with double-stick foam tape. The cars will function on the track even when the track is laying flat on the table. However, because of the wheel protectors, the cars will *not* roll on a flat surface without the track.

To create hills, lay the track over a stack of books or equivalent object. The track can be suspended in a configuration of your own design using any rod stands with half-inch diameter rods to which the track can be clamped.

Car assembly options

Wheel labels

Labels which simulate the look of a wheel are supplied for the user to apply to the flat circles of the car body.

Bumper (elastic and inelastic)

The bumper can be attached to the car with a thumbscrew through the hole in the center of the car. Orient the bumper so the circular indentation in it faces upward and is aligned with the car's circular mass tray. (See Figure 9.)

Figure 9: Top view of car with elastic bumper.

- To make an elastic bumper, use the small rubber bands supplied with the bumper. Stretch a rubber band across the bottom of the two prongs on the bumper as shown in Figure 9. For high speed collisions, you will need to double over the rubber band to make it stiffer.
- For inelastic collisions, remove the rubber band and put a small amount of Claytoon clay in the "V" slot on the bumper. (See Figure 10.)

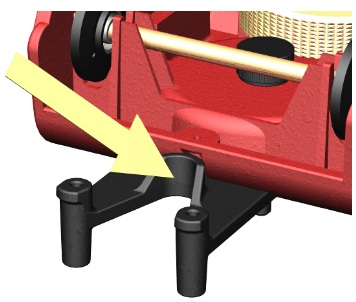


Figure 10: "V" slot on the bumper, where clay should be inserted to form an inelastic bumper.

Photogate flag for timing and acceleration studies

The photogate flag fits into a slot on either the left or right side of the car. The flag has two tabs to allow timing from the first time the photogate beam is blocked to the second time it is blocked. When using a photogate, connect the photogate stereo plug into a timing device, such as the Smart Timer (ME-8930), and vertically adjust the photogate so that the slit on the photogate aligns with the bottom of the gap on the flag, as seen in Figure 11. When the car passes through the photogate beam, the photogate will measure the time from the leading edge of the flag's front tab to the leading edge of the back tab.

Figure 11: Car with photogate flag moving toward a Photogate Head (ME-9498A).

Adding ballast mass and additional masses

The ballast mass fits underneath the car and is attached using an M5 screw (supplied with the Roller Coaster), as seen in Figure 12.

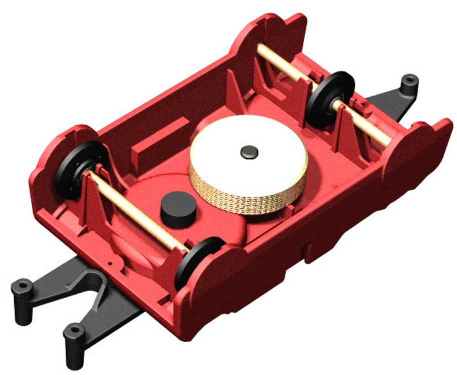


Figure 12: Ballast mass on underside of car.

Additional cylindrical masses can be placed on top of the car in the mass tray, as shown at left in Figure 13. If a bumper is installed on the car, the masses can instead be added by inserting a 6-32 screw up from the bottom of the car through the threaded hole in the bumper's mass tray. The masses fit over the threaded screw to help keep them from slipping off the car, as shown at right in Figure 13. Alternatively, the masses can be secured on the bumper by putting the screw in from the top.

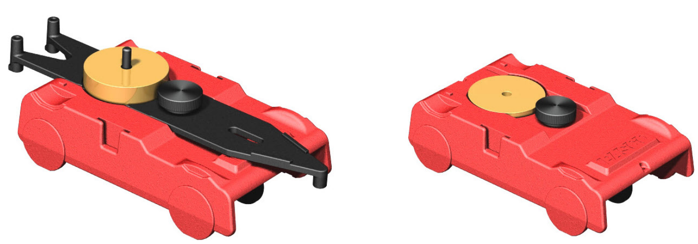


Figure 13: Left: Adding additional masses with a bumper. Right: adding additional masses without a bumper.

Coupling cars

The bumpers can be used to couple two or three cars together for a roller coaster train. To couple the cars, first put rubber bands on the bumpers as if creating elastic bumpers. Place the pointed front end of the bumper of the trailing car over the rubber band of the car in front of it, letting the front fit loosely into the "V" slot of the leading car. (See Figure 14.)

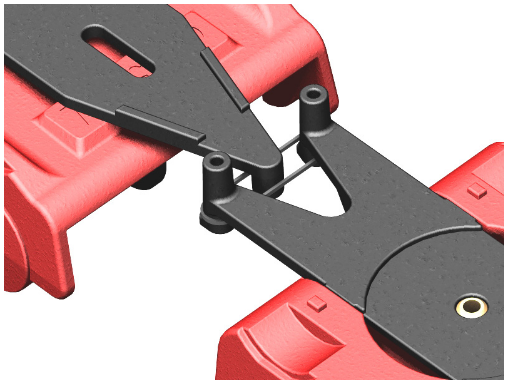


Figure 14: Two cars connected together.

Stacking two cars

One car can be stacked on top of another car to double the mass, as well as for storage purposes.

Car center of mass location

Without added masses, the center of mass of a car is approximately located in the center of the slot for the photogate flag. The exact location of the center of mass can be determined by balancing the car on a knife edge.

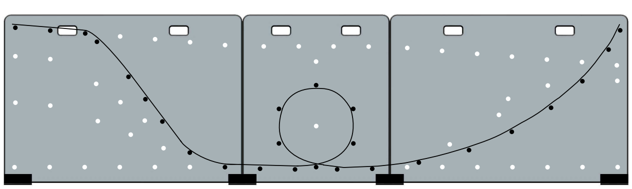
Suggested experiments

Experiment 1: Loop (one car)

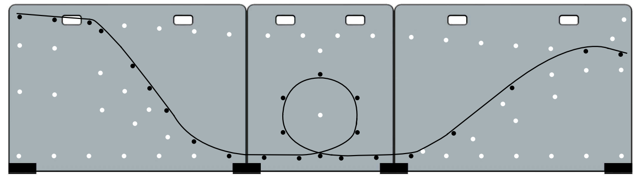
There are two basic configurations for this loop, shown in Configurations 1A and 1B. Both begin on the left using the highest track path, but there are two ways to end the track on the right. Configuration 1A is steep on one side and shallow on the other to emphasize that the car goes to the same height on each side (ignoring friction). Note that only one car can be used when starting on the highest track path, as multiple cars linked together will derail due to the following cars going too fast over the bend in the track.

Where does the car have to start from rest to just barely make it over the loop? Note that the car will also make it over the loop when it is started from the second highest path on the left.

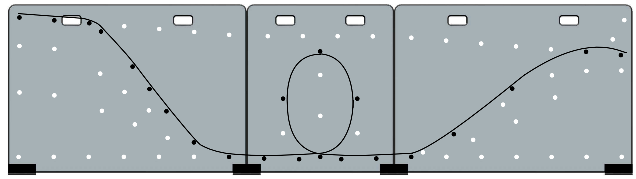
It is also possible to make a non-circular loop, as seen in Configuration 1C. Does the car have to be released at the same point as in the circular loop to make it over?



Configuration 1A: One car loop (Steep/shallow)



Configuration 1B: One car loop



Configuration 1C: Oval loop

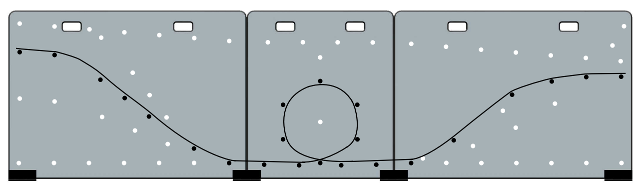
Experiment 2: Cup of water over loop

Place a cup of water in the mass tray of the car and let the car go around the loop. Put a catcher at the end of the track so the car will be caught instead of going back through the loop. Will the water stay in the cup as the car goes over the loop?

Experiment 3: Three-car coaster

When using three cars linked together as a roller coaster train, begin on the left on the step that is second from the top. (See Configuration 3.) Where must the coaster start to make it over the loop? The speeds of the first, middle, and last car can also be measured at any point along the track to show that the cars have different speeds as they pass over that point.

Place water in three cups and place one cup in the mass tray of each of the three cars. Will the water stay in each of the cups as they go over the loop?

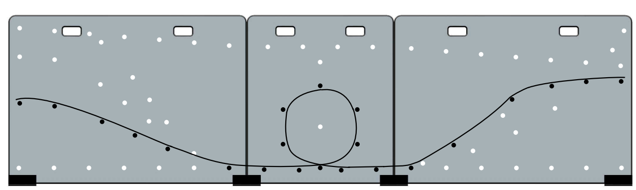


Configuration 3: Three-car coaster loop

Experiment 4: Collision between two cars at bottom of loop

Start a car with a ballast mass at the top of the lowest *step* on the left (the second peg from the bottom; see Configuration 4). Show that it does not make it over the loop.

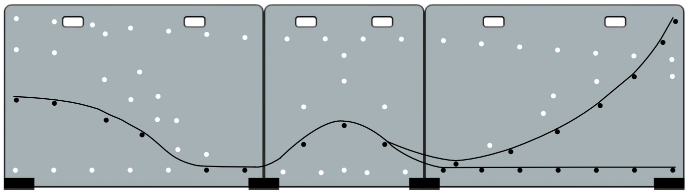
Place another car, this one without a ballast mass, at rest at the bottom of the loop. Start the car with the ballast from the top of the lowest step and let it collide elastically with the car at the bottom of the loop. Will the car at the bottom of the loop make it over the loop after the collision?



Configuration 4: Collision between two cars

Experiment 5: Conservation of energy (hills)

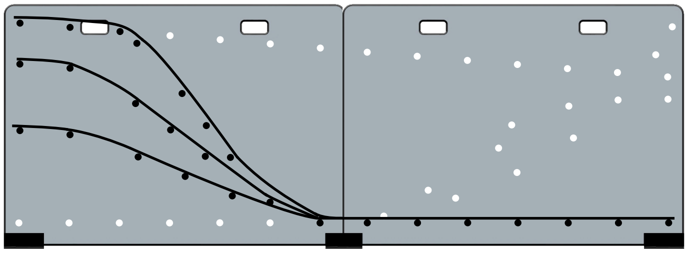
If the car is released from rest from the top of the lowest left step (see Configuration 5), the car will make it over the hill without flying off the hill. If the car is released from higher up on the right side, the car will fly off the hill. The speed of the car at the top of the hill can be measured with a photogate. From the speed value, the kinetic energy of the car can be calculated and compared to the predicted value given by conservation of energy. The normal force at the top of the hill can also be calculated.



Configuration 5: Conservation of energy (hill)

Experiment 6: Conservation of energy (step)

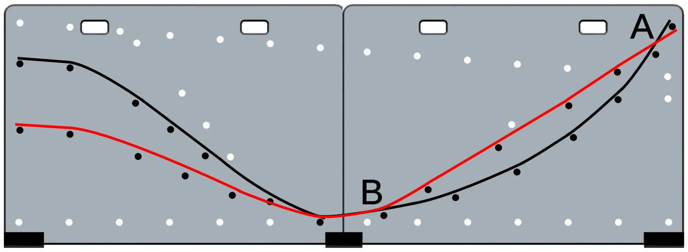
Use the setup in Configuration 6. Compare the potential energy at the top of each step to the kinetic energy at the bottom of the step.



Configuration 6: Conservation of energy (steps)

Experiment 7: Brachistochrone (black) vs. straight track (red)

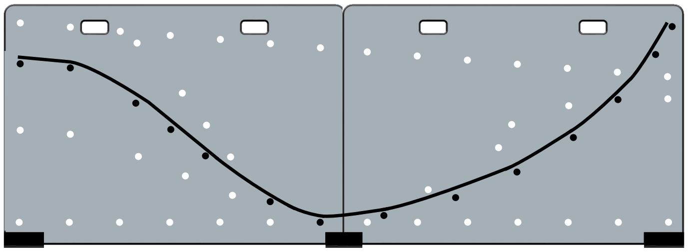
The shortest distance between two points is a straight line. In Configuration 7, which car will travel from Point A to Point B in the least time: the car on the curved track, or the car on the straight track?



Configuration 7: Brachistochrone vs. straight track

Experiment 8: Brachistochrone vs. brachistochrone at different start positions

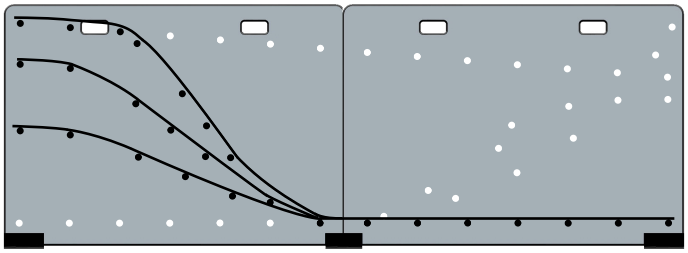
Put two tracks side by side along the brachistochrone path (see Configuration 8). Start one car at the top of one of the tracks and start the other car halfway down the other track. Release both cars at the same time and see which car reaches the bottom first. How does the time to go down the brachistochrone vary with different start positions?



Configuration 8: Brachistochrone vs. brachistochrone

Experiment 9: Acceleration down different inclined tracks

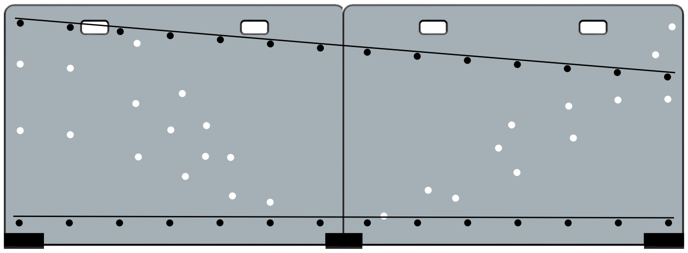
In Configuration 9, the three inclines on the left board form a straight line for a short distance. Measure the acceleration of the car on each of these inclines. The acceleration can be measured using two photogates on successive pegs and a Smart Timer set on the **ACCEL** measurement and **Two Gates** mode. Measure the angles of the inclines and calculate the theoretical accelerations.



Configuration 9: Acceleration on different inclines

Experiment 10: Collisions on a level track

Set up the track as shown in Configuration 10. The flat track at the bottom of the boards can be used for elastic and inelastic collisions. Two or three boards can be used to make tracks of different lengths.



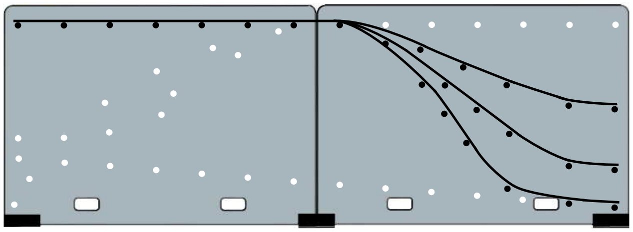
Configuration 10: Collisions on a level track

Experiment 11: Acceleration of car by mass on string over pulley

The pulley fits on the catcher at the end of the track. A photogate can be attached to the peg that goes through the catcher, and the photogate can be positioned so the pulley will break the beam. Use these features to measure the acceleration of a car as it is pulled by a mass on a string over the pulley.

Experiment 12: Projectile car off end of track (3 steps)

Turn the support boards upside-down and set up the track as shown in Configuration 12. Allow the car to go off the end of the track onto the floor in projectile motion. (Place some sort of cushion on the floor to soften the impact.) From which of the three steps will the car go furthest?

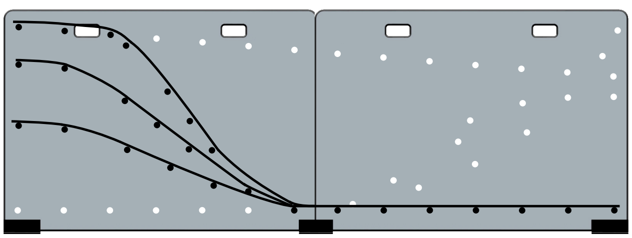


Configuration 12: Projectile car off end of track

Experiment 13: Projectile car off end of track after colliding with car at end of track

Set up the track as shown in Configuration 13. Set a car at rest at the end of one of the tracks. Let a second car roll down the track and collide with the resting car so that it falls onto a cushion on the floor. Try to predict where the car will land for each track.

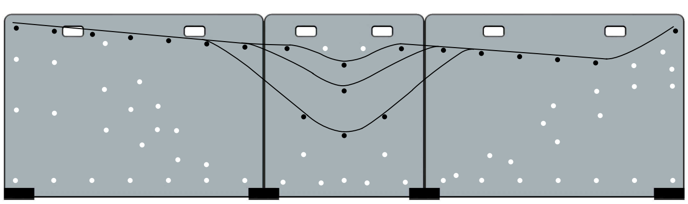
If a mass is added to the rolling car, the two cars will go off the end of the track at different speeds. Try to predict where each car will land.



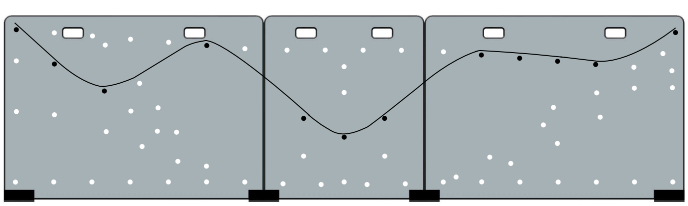
Configuration 13: Projectile car after collision

Experiment 14: Oscillations in a well

Set up the track as shown in Configuration 14A *or* 14B. Start a car moving in one of the valleys and time the period of the oscillations. Depending on initial speed and position, the car will be trapped in one of several potential wells.



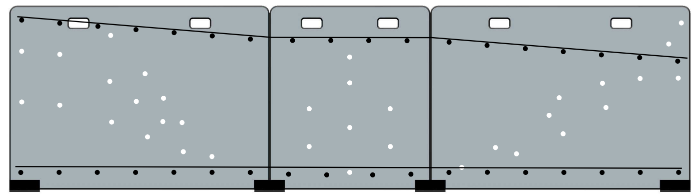
Configuration 14A: Oscillations in a well



Configuration 14B: Potential wells

Experiment 15: Position, velocity, and acceleration

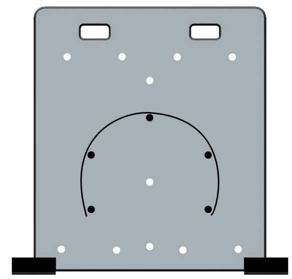
Set up the track as shown in Configuration 15. In this setup, the car travels down a straight slope on the first board, along a level path on the second board, and then down another straight slope on the third board. Ask students to predict the shape of the position versus time, velocity versus time, and acceleration versus time graphs of the car. Once predictions are made, show students the motion of the car and make measurements using photogates and a Smart Timer.



Configuration 15: Position, velocity, and acceleration

Experiment 16: Circular track

Make a circular track as shown in Configuration 16, with the car side of the track on the outside of the circle. Start the car from rest on top of the track and determine the point at which the car leaves the track and flies off. To determine this, set up a photogate near where the car appears to leave the track. Adjust the photogate's position so the car flag just barely does not block the photogate when the car is run along the circular track by hand. Then allow the car to roll down the track and fly off. If the car has indeed left the track when it reaches the photogate, the car flag will block the gate and a Smart Timer will record the car's speed.



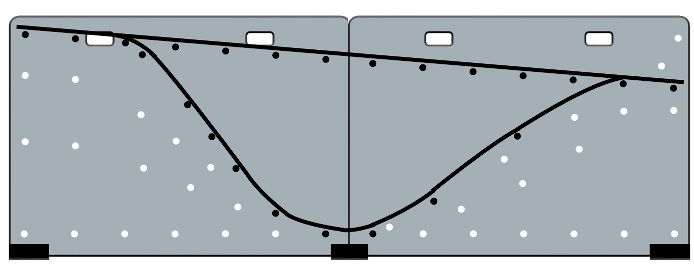
Configuration 16: Circular track

Use conservation of energy to predict the angle at which the car should leave the track.

Experiment 17: High road and low road

Set up two tracks side-by-side, as shown in Configuration 17, and race two cars down them. Which car will win? What are the final speeds of the cars at the end of the track when they are back together?

> **TIP:** For demonstrations, try hanging a cloth on the pegs of the high road to hide the low road from view. The car on the low road will disappear behind the cloth and reappear on the other side in a surprisingly short time.



Configuration 17: High road vs. low road

Technical support

Need more help? Our knowledgeable and friendly Technical Support staff is ready to answer your questions or walk you through any issues.

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