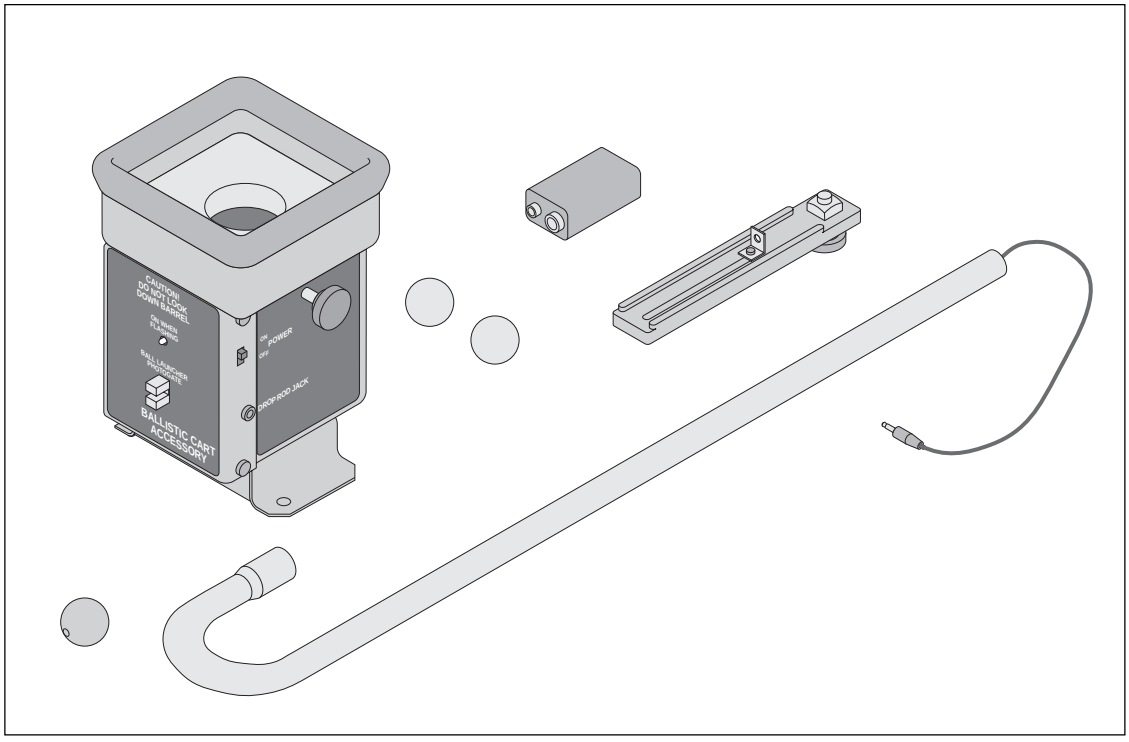
Instruction Manual and Experiment Guide for the PASCO scientific Model ME-9486

012-05460A
7/94

BALLISTIC CART ACCESSORY



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This manual authored by: Jon Hanks and Eric Ayars

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NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

① The carton must be strong enough for the item shipped.

② Make certain there is at least two inches of packing material between any point on the apparatus and the inside walls of the carton.

③ Make certain that the packing material can not shift in the box, or become compressed, thus letting the instrument come in contact with the edge of the box.

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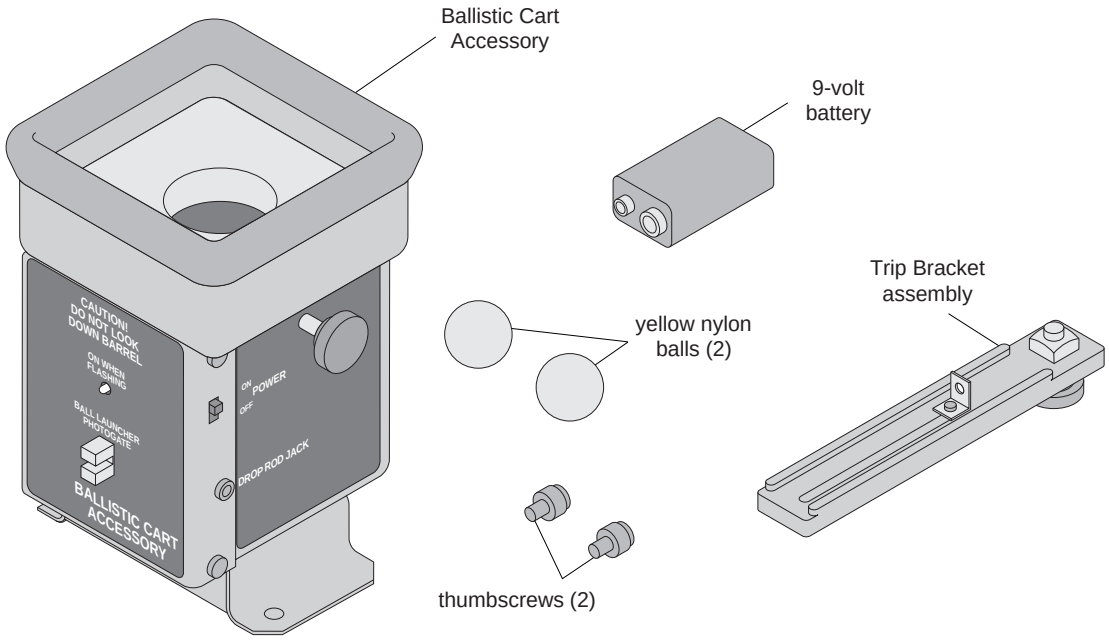
Introduction

The PASCO ME-9486 Ballistic Cart Accessory is used with the PASCO Dynamics Cart and track (ME-9429A or ME-9452) to shoot a plastic ball straight up from the moving cart. If the cart is moving at a constant velocity, the ball will fall back into the catcher on the cart. The ball is released using a photogate so there is no impulse given to the cart upon release as there is in other models which used a string to release the ball. The barrel can be aimed to ensure that the ball is shot vertically. Special no-bounce foam prevents the ball from bouncing back out of the catcher cup.

The PASCO ME-9487 Drop Rod Accessory can be mounted to the Ballistic Cart Accessory so a special plastic ball can be dropped from rest (relative to the cart) above the moving cart. Also the drop rod can be rotated away from the cart so the ball will drop onto the floor to perform bombing runs.

➤ NOTE: It is better to use a 2.2 m track (ME-9452) rather than the 1.2 m track (ME-9429A) because it gives you more room to work.

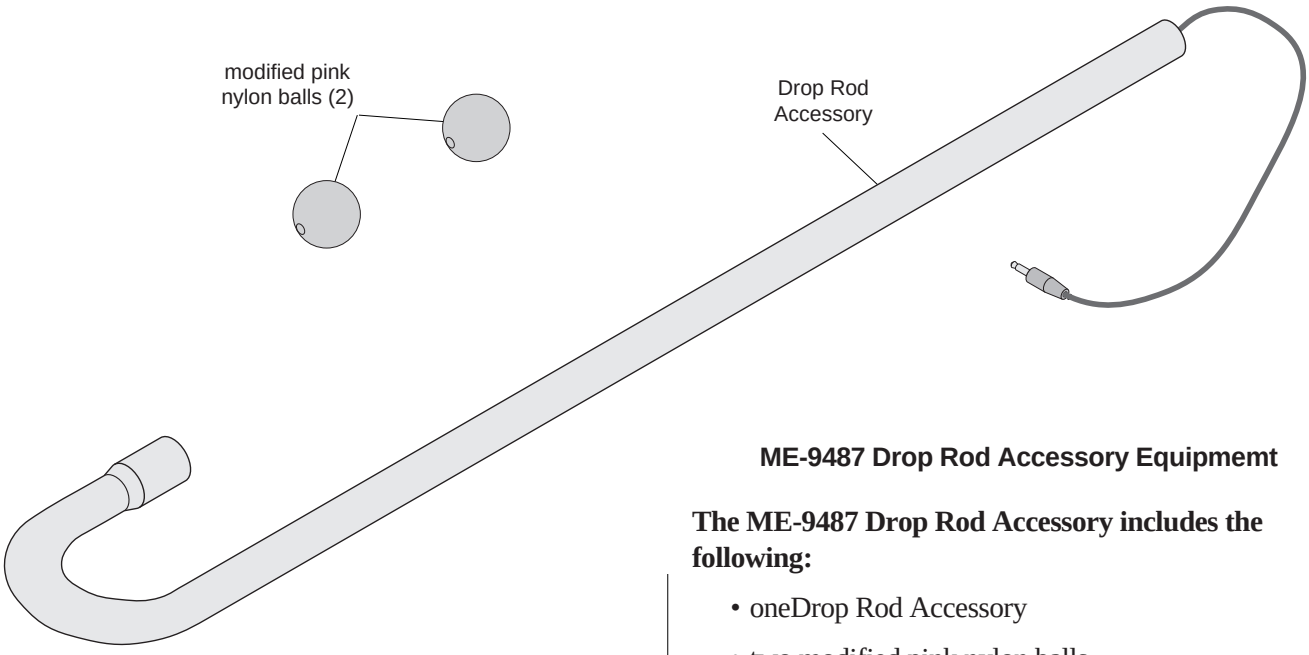
Equipment



ME-9486 Ballistic Cart accessory Equipment

The ME-9486 Ballistic Cart Accessory includes the following:

- one Ballistic Cart Accessory
- one Trip Bracket assembly
- one 9-volt battery
- two yellow nylon balls
- two thumbscrews



ME-9487 Drop Rod Accessory Equipmemt

The ME-9487 Drop Rod Accessory includes the following:

- oneDrop Rod Accessory
- two modified pink nylon balls

Assembly

ME-9486 Ballistic Cart Accessory

Battery Installation

① Turn the unit on its side and install the 9-volt battery in the bottom of the unit. See Figure 1.

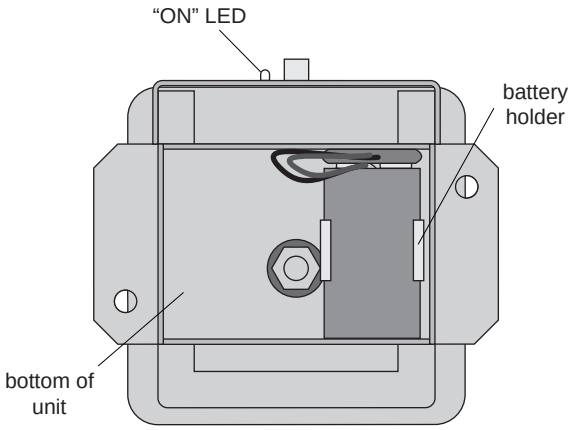


Figure 1: Battery Installation

Attaching the Ballistic Cart Accessory to a Dynamics Cart

① Remove the two mounting screws (see Figure 2) from their storage place on the side of the unit. (There are two extra screws included with the Ballistic Cart Accessory.) Use these screws to attach the Ballistic Cart Accessory to the mass tray of the dynamics cart.

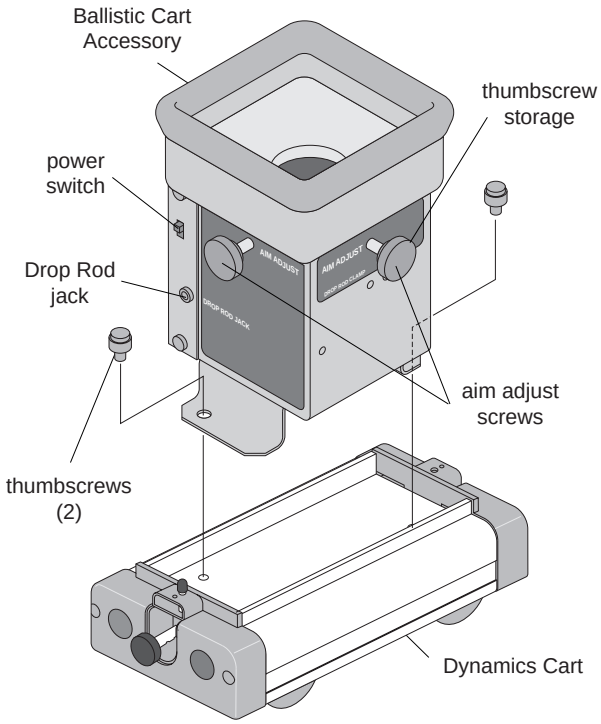


Figure 2: Ballistic Cart Installation

② Slide the photogate trip bracket into the T-slot on the dynamics track. See Figure 3.

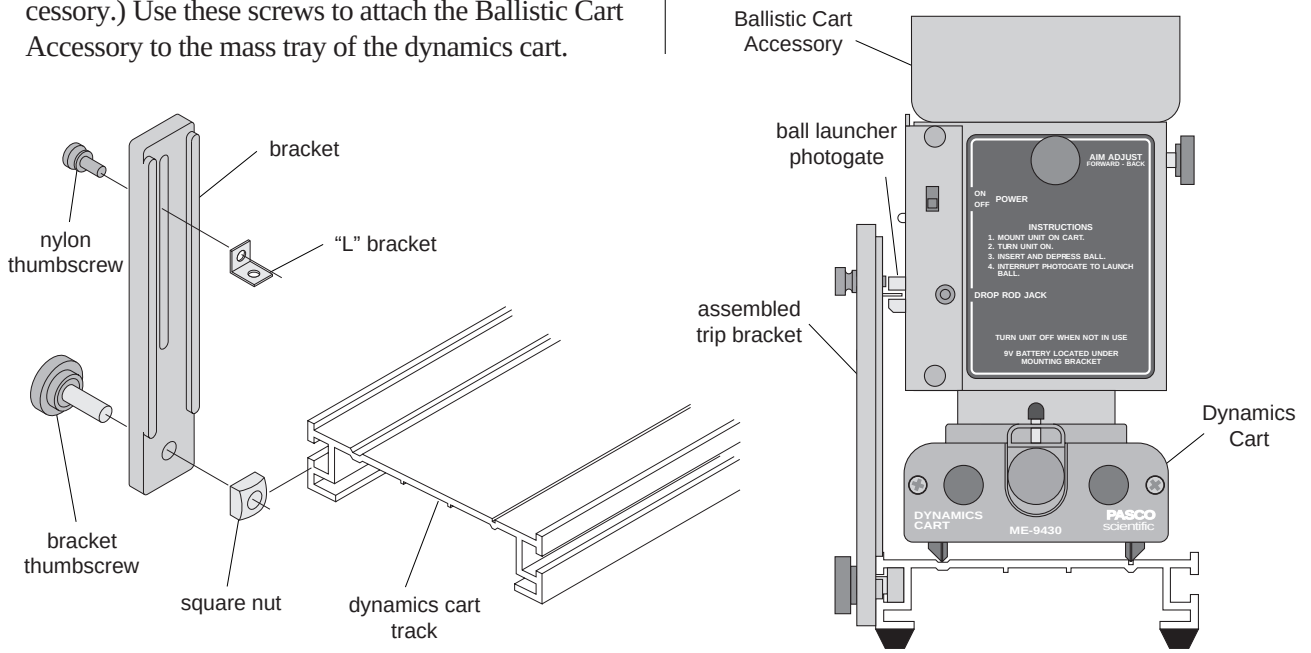


Figure 3: Using the Trip Bracket

Setting Up the Ballistic Cart Accessory

① Move the aim adjusting screws (see Figure 2) in and out to check that the barrel moves freely. Do this by looking down the barrel while adjusting the screws. If the barrel sticks it is because the foam catches it. To remedy this, gently lift up slightly on the edges of the foam to unstick it from the barrel.

② Level the dynamics track. To check if the track is level, place the cart on the track and give it a small push in one direction. Then push it in the opposite direction to see if the cart rolls easier in one direction than the other. Also make the track level from side-to-side by placing the plastic ball at rest on the track to see if it rolls one way or the other.

③ With the cart at rest on the level track, adjust the aim adjust screws until the ball shoots straight up and lands back in the catcher cup. Use a penny or dime to trip the photogate when the cart is at rest. Remember, the power switch must be turned on before the trip switch will operate. The LED will blink while the power is on. Also remember to turn the power switch off before storing the accessory.

➤ **NOTE:** The trip switch must be mounted on the same side as the photogate on the Ballistic Cart. See Figure 3.

ME-9487 Drop Rod Accessory

Drop Rod Installation

① Use the $1^1/_2$ inch metal screws to fasten the drop rod clamp to the side of the Ballistic Cart Accessory. See Figure 4. Screw the thumb screw into the end of the drop rod clamp.

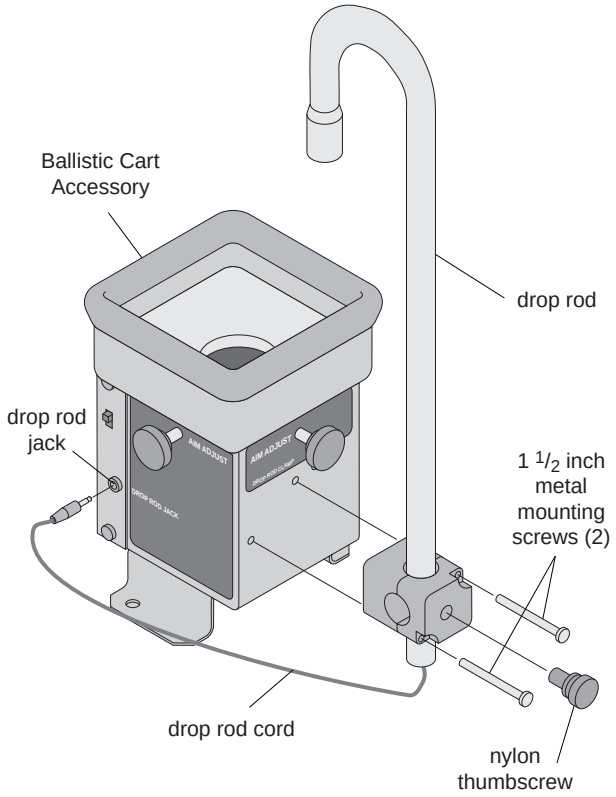


Figure 4: Drop Rod Installation.

② Thread the cord from the drop rod through the drop rod clamp and clamp the end of the drop rod by tightening the thumb screw.

➤ **CAUTION:** Do not over-tighten the screw or the tube may be crushed.

③ Plug the drop rod cord into the drop rod jack on the side of the Ballistic Cart Accessory.

➤ **NOTE:** Plugging this cord in disables the launching mechanism of the Ballistic Cart Accessory so when you want to use the launcher you must unplug the drop rod accessory.

④ Note that the Drop Rod Accessory requires a special ball that has an iron insert. The balls for the Drop Rod Accessory and the Ballistic Cart Accessory are different colors so they can be easily distinguished. To hang the ball from the drop rod, the pin on the drop rod must be inserted into the small hole in the ball. See Figure 5.

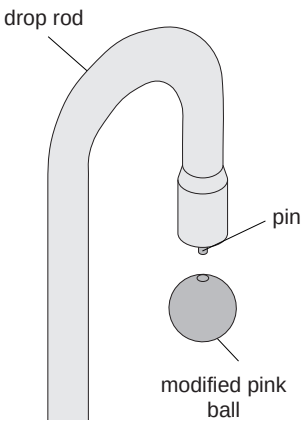


Figure 5: Ball and Drop Rod

Experiment 1: Shoot and Catch - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track (ME-9452)

Purpose

This demonstration shows that when the ball is shot vertically upward from the cart while the cart is moving at any constant speed, the ball will land back in the cart.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② With the cart at rest on the track, load the ball and trip the release mechanism with a penny or other opaque object. This proves to the students that the ball is being launched straight up.

③ Put the photogate trip bracket near one end of the track, leaving enough room to push the cart up to its maximum speed before it reaches the trip bracket. See Figure 1.1. Load the ball and start the cart from that end of the track by giving the cart a gentle push. The cart will move slowly and the ball will be caught.

④ Return the cart to the end of the track. Load the ball and give the cart a stronger push.

➤ **CAUTION!** You must catch the cart with your hand before the cart reaches the end stop on the track because the cart will derail when it's moving fast. The ball will be caught at any cart speed.

➤ **NOTE:** If you have the Drop Rod Accessory, try putting it on the Ballistic Cart Accessory to act as a reference line. With this reference line, the ball appears to go straight up and down. Without the reference, the ball may appear to go in a parabola.

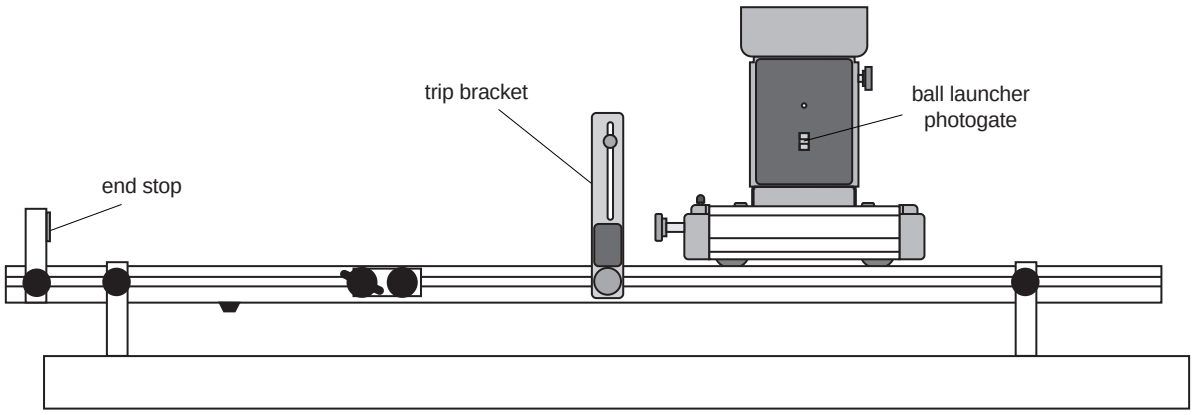


Figure 1.1: Setup for Shoot and Catch

Notes:

Experiment 2: Tunnel - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– Cardboard box (33 cm {13"} cube) for tunnel (construction details given below)

Purpose

This demonstration shows that the ball can be caught by the cart even if the cart passes through a tunnel while the ball is in the air. The tunnel accentuates the parabolic path of the ball.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② Construct a tunnel from a cardboard box: Cut the flaps off two opposing ends of the box. Cut a 15 cm wide, 27 cm high hole in these two opposing ends of the box. See Figure 2.1.

③ Set the box upside-down over the middle of the dynamics track. Check the clearance by running the cart through the tunnel.

④ Position the photogate trip bracket in front of the tunnel so the ball will be launched just before the cart enters the tunnel.

⑤ Load the ball and push the cart toward the tunnel. You may have to practice to get the right speed so the cart will make it through the tunnel before the ball comes down.

➤ **CAUTION!** You must catch the cart with your hand before the cart reaches the end stop on the track because the cart will derail when it's moving fast.

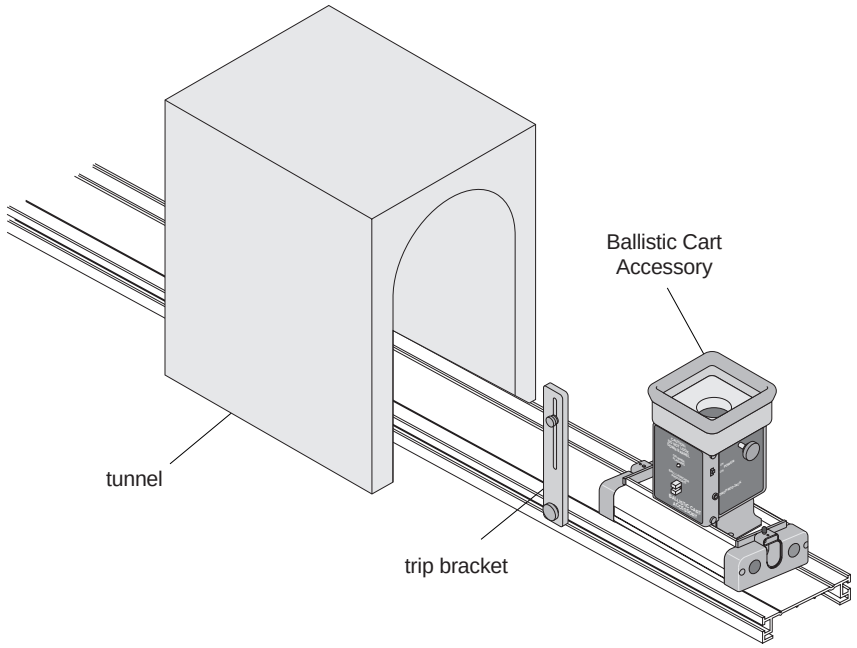


Figure 2.1: Tunnel

Notes:

Experiment 3: Accelerating Cart - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– String
– Clamp-on pulley
– 50 gram mass and mass hanger

Purpose

This demonstration shows that when the ball is shot vertically upward from the cart while the cart is accelerating, the ball will not land in the cart.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② Clamp the pulley to the end of the track. Attach a string (about 1 meter long) to the cart and pass it over the pulley. Hang about 50 grams on the string. See Figure 3.1.

③ Put the photogate trip bracket in a position where it will launch the ball after the cart has begun to move.

④ Start the cart as far back as possible, load the ball, and let it go. In this case, the ball will fall behind the cart.

➤ **CAUTION!** You must catch the cart with your hand before the cart reaches the end stop on the track because the cart will derail when it's moving fast.

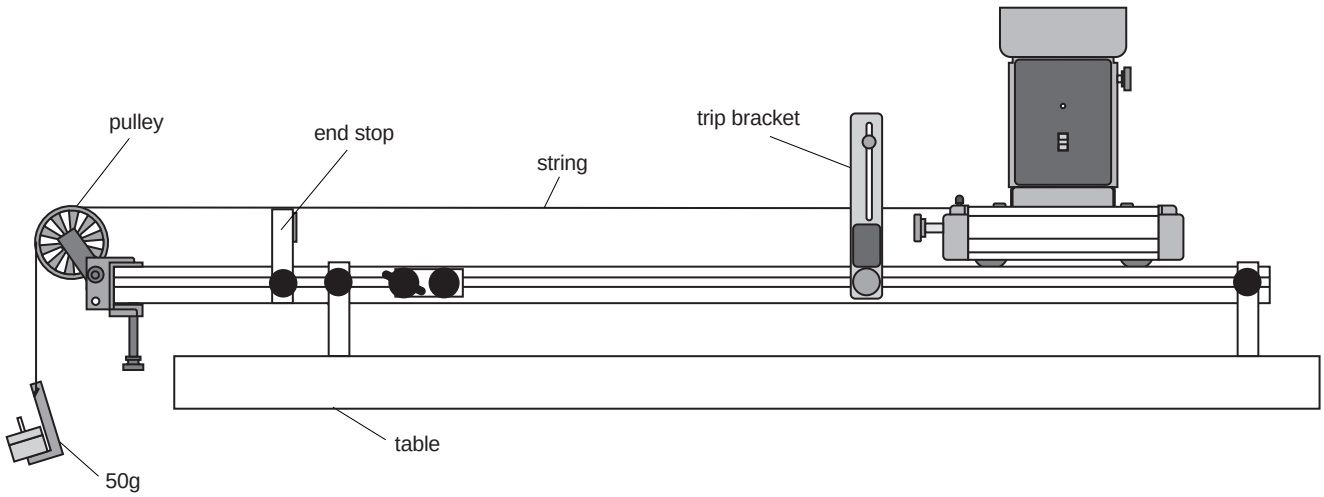


Figure 3.1: Accelerating Cart.

Notes:

Experiment 4: Inclined Plane - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– Table clamp and rod
– Rod clamp for dynamics track

Purpose

This demonstration shows that a ball launched from a cart that is accelerating down an inclined plane will be caught by the cart regardless of the angle of incline.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② Incline the track using the table clamp and rod. See Figure 4.1. Be careful not to choose too high an angle because the cart will reach such a high speed that it will crash at the bottom. For any angle you choose, be sure you catch the cart at the bottom to keep it from derailing and crashing to the floor.

③ Put the photogate trip bracket in a position where it will launch the ball after the cart has begun to move.

④ Start the cart at the top of the incline, load the ball, and release the cart. The ball will land in the cart.

➤ **CAUTION!** Remember to catch the cart!

⑤ Repeat the demonstration for a different angle.

⑥ Start the cart at the bottom of the incline. Give the cart a push uphill so that it travels past the trip bracket.

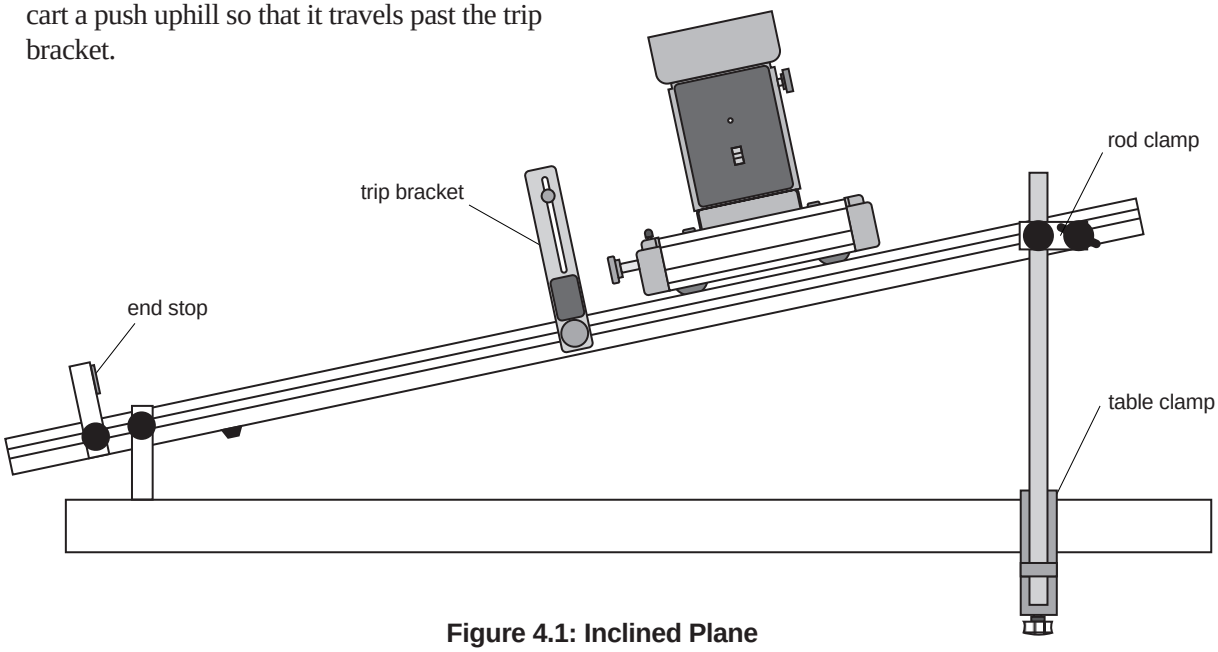


Figure 4.1: Inclined Plane

Notes:

Experiment 5: Drop Ball - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– Drop Rod Accessory (ME-9487)

Purpose

The purpose of this demonstration is to show that when the ball is dropped from the drop rod while the cart is moving at any constant speed, the ball will land in the cart.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② Position the drop rod so that the ball will be directly over the cup. See Figure 5.1.

③ With the cart at rest on the track, hang the ball on the drop rod and trip the release mechanism with a penny or other opaque object. This shows the students that the ball is drops straight down and is caught by the cart.

④ Put the photogate trip bracket near one end of the track, leaving enough room to push the cart up to its maximum speed before it reaches the trip bracket. Hang the ball from the drop rod and give the cart a gentle push.

⑤ Return the cart to the end of the track. Hang the ball from the drop rod and give the cart a stronger push. The ball will be caught at any cart speed.

➤ **CAUTION!** You must catch the cart with your hand before the cart reaches the end stop on the track because the cart will derail when it's moving fast.

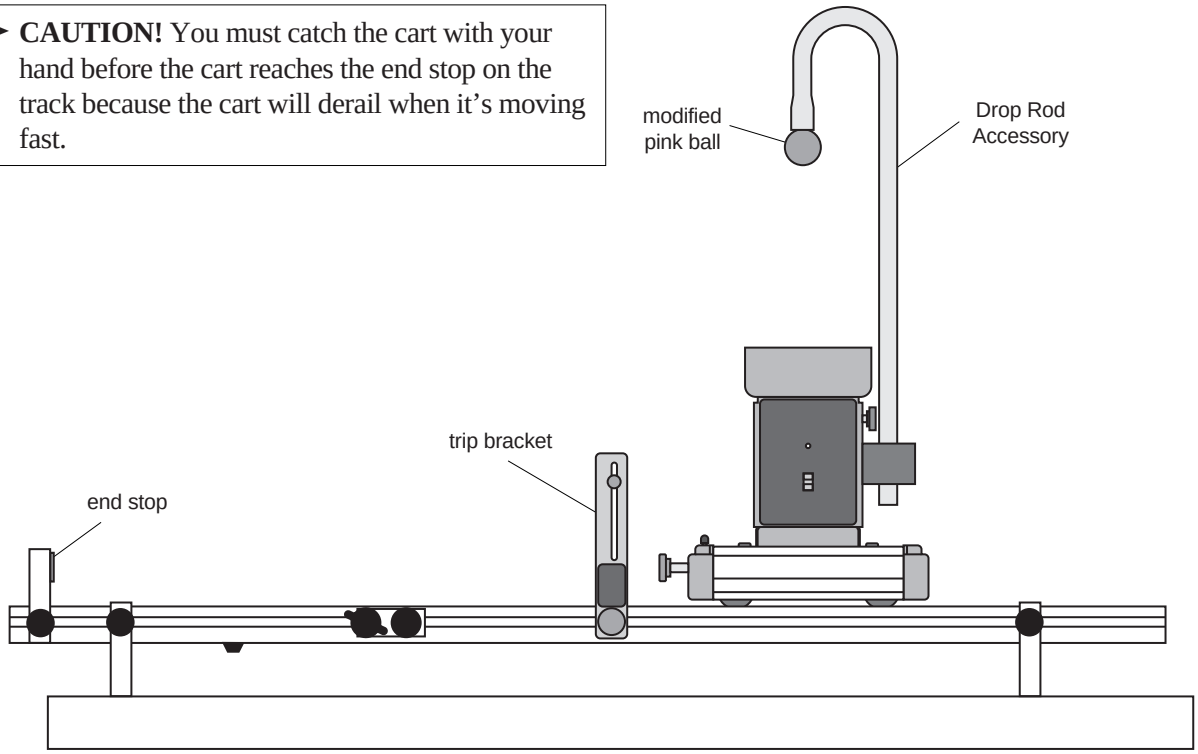


Figure 5.1: Setup for Drop Ball

Notes:

Experiment 6: Accelerating Cart - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– Drop Rod Accessory (ME-9487)
– String
– Clamp-on pulley
– 50 gram mass and mass hanger

Purpose

This demonstration shows that when the ball is dropped from the drop rod on a cart that is accelerating, the ball will not land in the cart.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② Position the drop rod so that the ball will be directly over the cup.

③ Clamp the pulley to the end of the track. Attach a string (about 1 meter long) to the cart and pass it over the pulley. Hang about 50 grams on the string. See Figure 6.1.

④ Put the photogate trip bracket in a position where it will drop the ball after the cart has begun to move.

⑤ Start the cart as far back as possible, hang the ball on the drop rod, and release the cart. In this case, the ball will fall behind the cart.

➤ **CAUTION!** You must catch the cart with your hand before the cart reaches the end stop on the track because the cart will derail when it's moving fast.

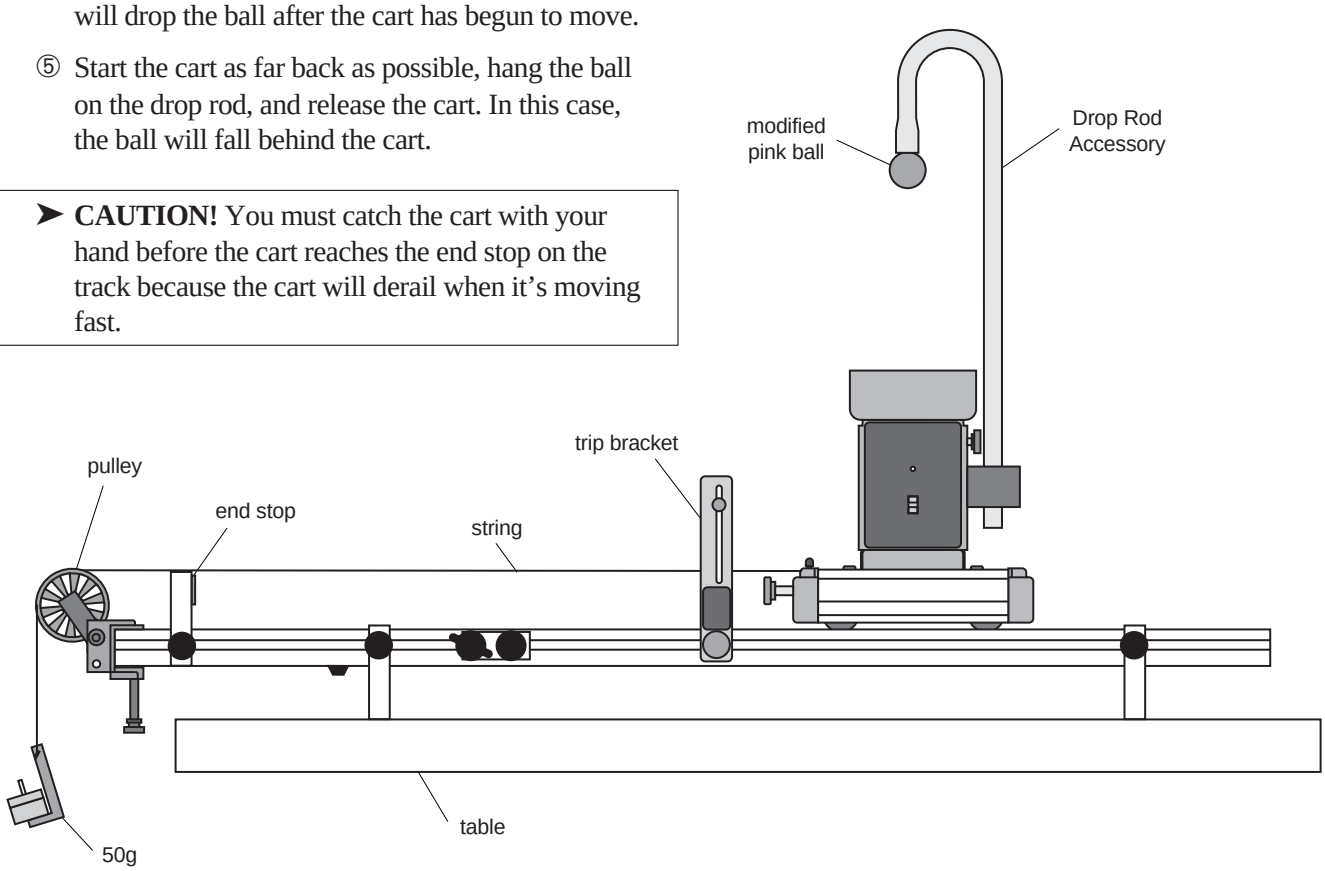


Figure 6.1: Accelerating Cart

Notes:

Experiment 7: Inclined Plane - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– Drop Rod Accessory (ME-9487)
– Table clamp and rod
– Rod clamp for dynamics track

Purpose

This demonstration shows that a ball dropped from the drop rod on a cart that is accelerating down an inclined plane will be caught by the cart regardless of the angle of incline.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

② Position the drop rod so that when the track is level, the ball will be directly over the cup.

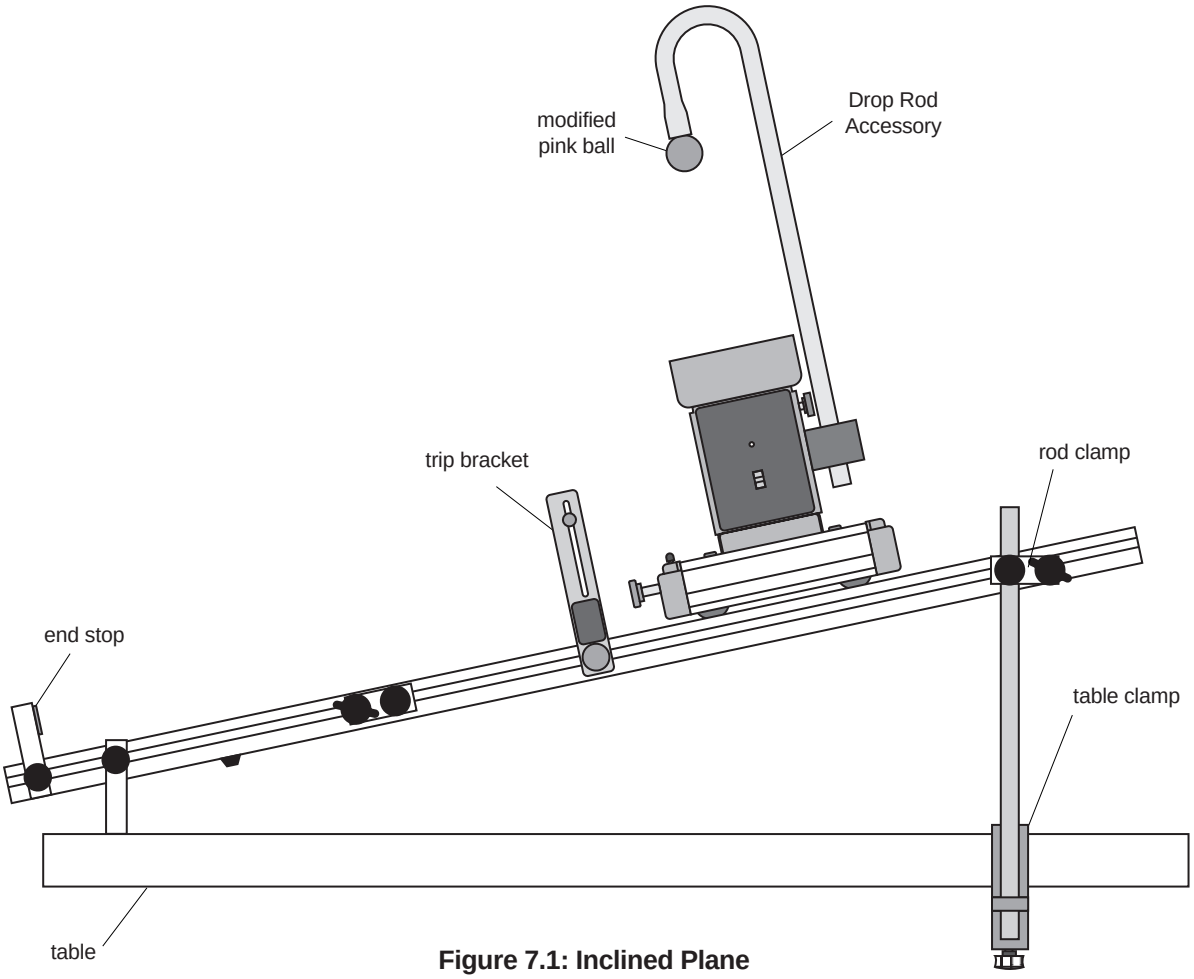


Figure 7.1: Inclined Plane

③ Incline the track (see Figure 7.1) using the table clamp and rod. Be careful not to choose too high an angle because the cart will reach such a high speed that it will crash at the bottom. For any angle you choose, be sure you catch the cart at the bottom to keep it from derailing and crashing to the floor.

④ Put the photogate trip bracket in a position where it will drop the ball after the cart has begun to move.

⑤ Start the cart at the top of the incline, hang the ball on the drop rod, and release the cart. The ball will land in the cart.

➤ **CAUTION!** Remember to catch the cart!

⑥ Repeat the demonstration for a different angle.

Experiment 8: Bombing Run - Demonstration

EQUIPMENT NEEDED

– Ballistic Cart Accessory (ME-9486)
– Dynamics Cart and track
– Drop Rod Accessory (ME-9487)
– Paper cup (for catching ball)

Purpose

This demonstration shows the students that a bomber must release the bomb before the plane is over the target.

Procedure

① Prior to the beginning of the demonstration, perform the Setup procedure.

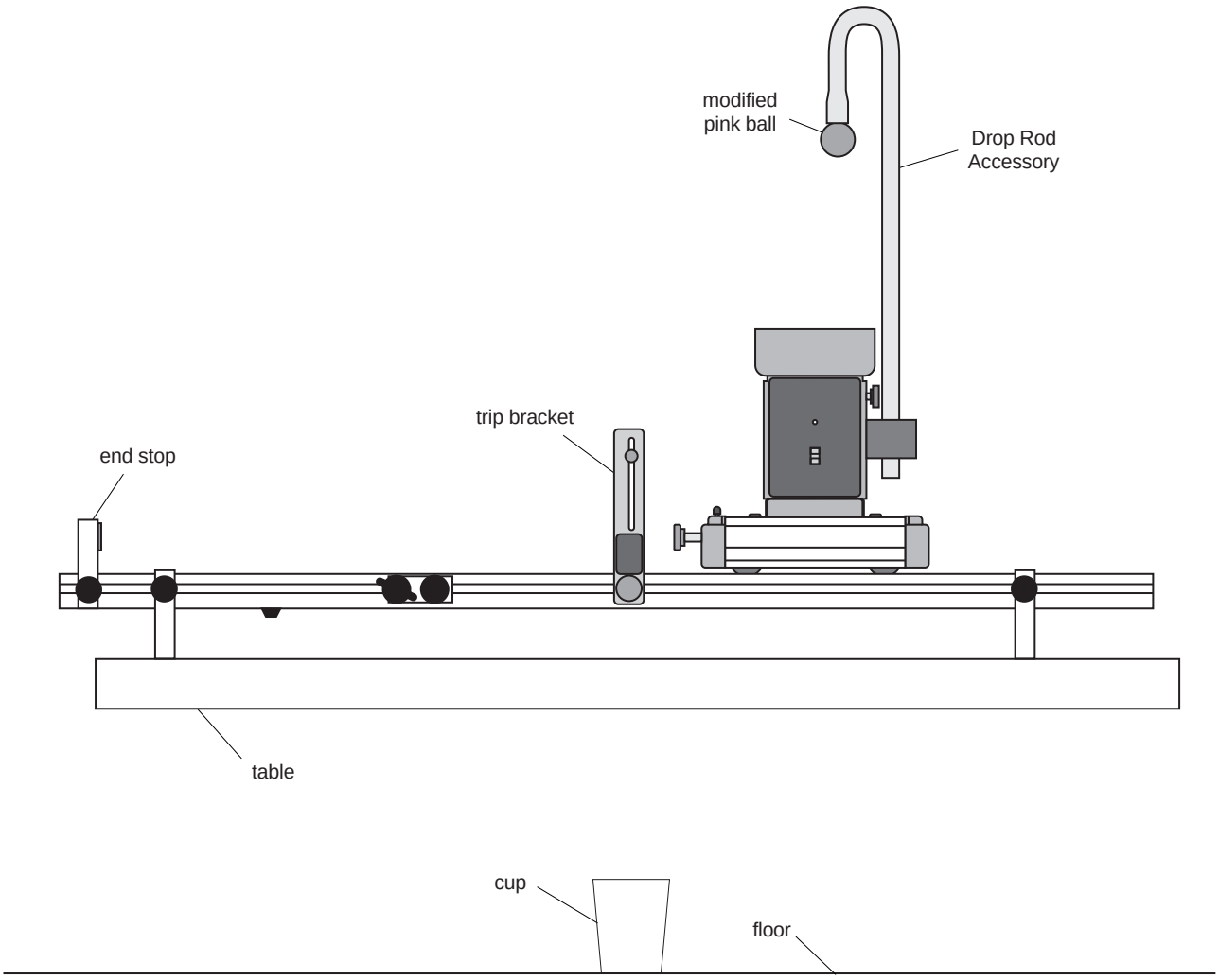


Figure 8.1: Bombing Run

② Align the track with the edge of the table.

③ Position the drop rod so that as the ball drops, it will miss the table and fall to the floor.

④ Position the photogate trip bracket near the middle of the track.

⑤ Place the cart on the track at the position of the trip bracket and place the cup on the floor under the drop rod. Pull the cart back to one end of the track, hang the ball on the drop rod, and push the cart. The ball will be dropped at the moment the cart passes over the cup. See Figure 8.1.

⑥ Discuss with the students the reason the ball misses the cup.

⑦ Move the trip bracket back and try it again.

Experiment 9: Bombing Run (Computerized)

EQUIPMENT NEEDED

- Ballistic Cart Accessory (ME-9486)
- Dynamics Cart and 2.2 m track (ME-9452)
- Drop Rod Accessory (ME-9487)
- Paper cup (for catching ball)
- Physics string (SE-8050) (NOTE: Stiff string is required.)
- Clamp-on pulley
- 200-gram mass and mass hanger
- Photogate and photogate bracket
- Computer
- Plumb bob
- Meter stick

Purpose

In this experiment, the distance from the target that a bomber must release the bomb is calculated and verified.

Procedure

① Prior to the beginning of the experiment, perform the Setup procedure.

② Align the track with the edge of the table.

③ Position the drop rod so that as the ball drops, it will miss the table and fall to the floor.

④ Position the photogate trip bracket near the middle of the track.

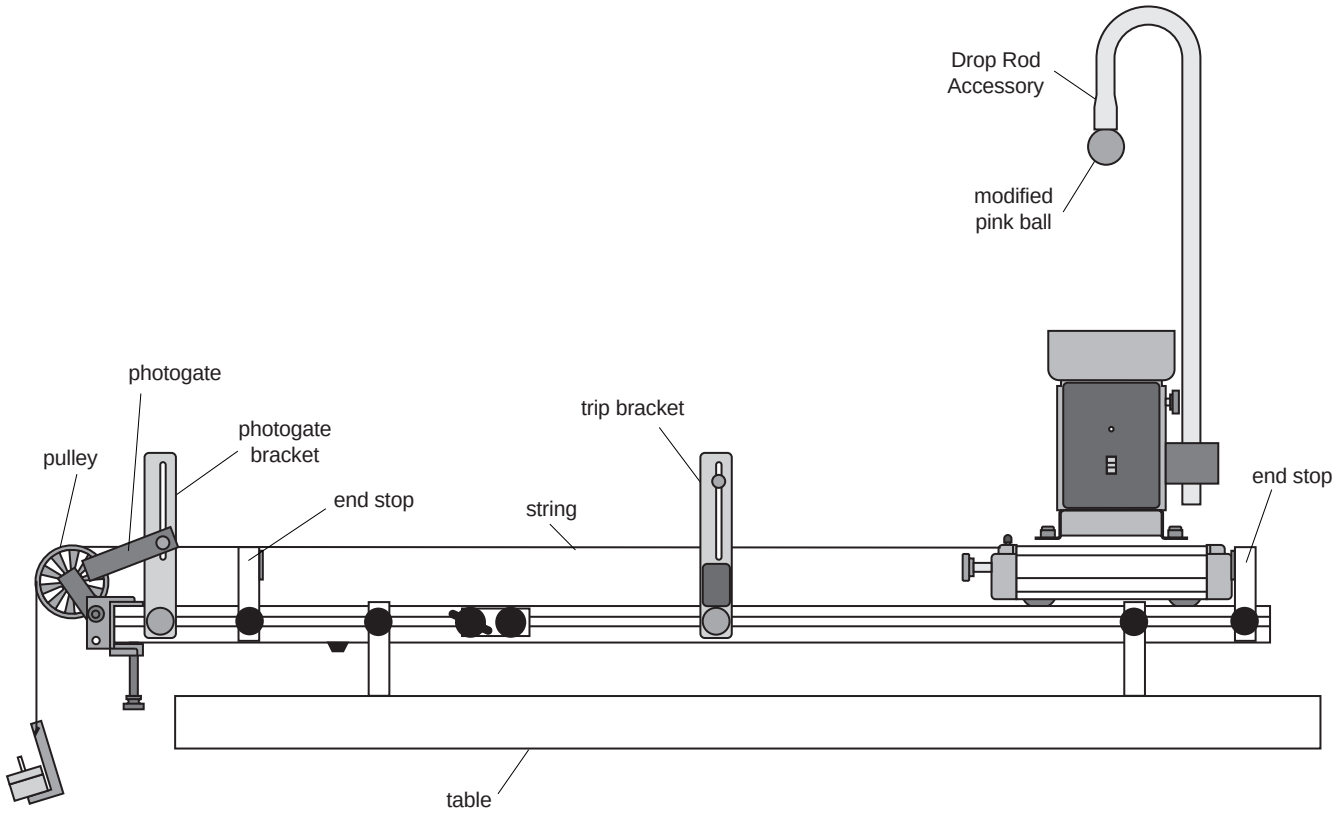


Figure 9.1: Smart Pulley Setup for Bombing Run

⑤ Clamp the pulley on the end of the track. Position the photogate and its bracket over the clamp-on pulley so it acts as a Smart Pulley. See Figure 9.1.

⑥ Tie one end of a 2.2-meter long string to the cart and pass the other end over the pulley and hang about 200 g on it.

➤ **NOTE:** the string must be long enough so the cart can reach the end stop furthest from the pulley. The end stop will mark the position where the cart will be started from rest each time.

⑦ Move the cart toward the pulley until the mass just touches the floor. Then place the trip bracket at the cart's position. This will cause the cart to drop the ball after the cart has reached its constant speed. Note that the stiff string will continue to move forward and not bunch up under the cart. This is the reason for not using thread.

⑧ Without hanging the ball on the drop rod, pull the cart back against the end stop and release it from rest. Record data with the computer and determine the maximum speed, v, of the cart.

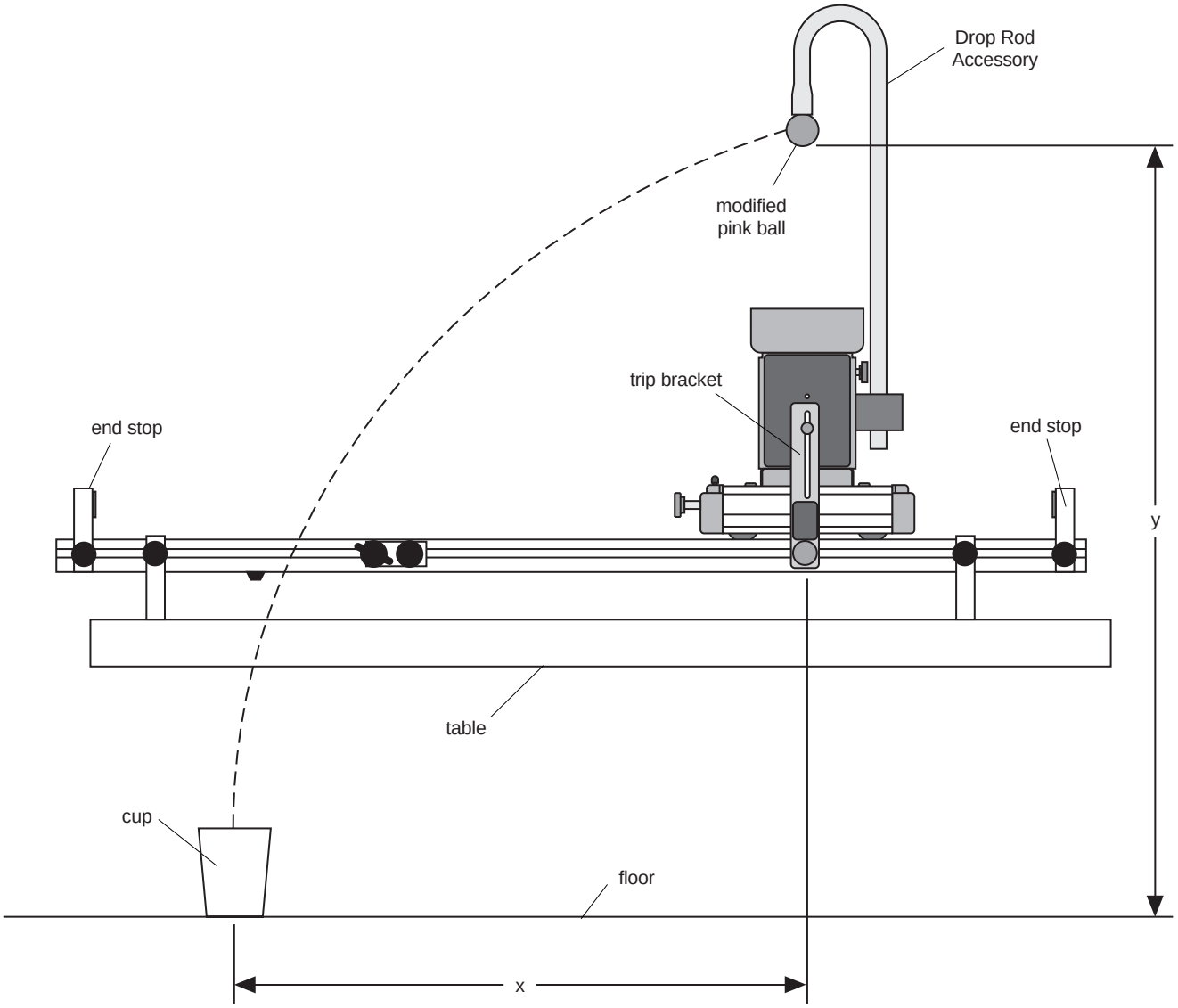


Figure 9.2: Projectile Motion For Bombing Run.

➤ **NOTE:** It is also possible to determine the speed using conservation of energy without a computer. You would need to know the mass of the Ballistic Cart Accessory and measure the distance the hanging mass falls.

⑨ Hang the ball on the drop rod and measure the distance, ***y***, from the bottom of the ball down to the floor. See Figure 9.2.

⑩ The vertical distance, ***y***, that the ball falls is given by

$$y = \frac{1}{2} gt^2$$

Using your measured value for ***y***, calculate the time it takes for the ball to fall.

$$t = \sqrt{\frac{2y}{g}}$$

⑪ Calculate the horizontal distance, ***x***, that the ball travels.

$$x = vt$$

This is the position where the ball should land.

⑫ Use a plumb bob and meter stick to measure off the distance, ***x***. Place a paper cup at this position on the floor.

⑬ Hang the ball from the drop rod, pull the cart back against the end stop and release it from rest. Observe whether or not the ball goes into the cup.

Questions

① Did the ball land in the cup? If not, why not?

② What are some of the possible sources of error in this experiment that would cause the ball to miss?

Notes:

Experiment 10: Bombing Run (Non-Computerized)

EQUIPMENT NEEDED

- Ballistic Cart Accessory (ME-9486)
- Dynamics Cart and track (ME-9452)
- Drop Rod Accessory (ME-9487)
- Paper cup (for catching ball)
- String
- Clamp-on pulley
- 50-200g mass and hanger
- Scale
- Plumb bob
- Meter stick

Purpose

In this experiment, the distance from the target that a bomber must release the bomb is calculated and verified. Instead of using a constant-velocity cart, we will use a known acceleration for a known distance to obtain a repeatable velocity at the time of release.

Theory

We can measure the distance that the cart will accelerate before dropping the ball (***d*** in Figure 10.1) and the height ***y*** that the ball will fall. Knowing the mass of the cart and the hanging mass, we can predict where the ball will land.

First, the velocity of the cart after travelling a distance ***d*** from rest will be

$$v_o = \sqrt{2ad}$$

where ***a*** is the acceleration of the system. The horizontal distance ***x*** that the ball will travel during its fall will be

$$x = v_o t_y$$

where ***ty*** is the time it takes for the ball to fall:

$$t_y = \sqrt{\frac{2y}{g}}$$

Combining these terms gives us:

$$x = \sqrt{2ad}\sqrt{\frac{2y}{g}} = 2\sqrt{\frac{ady}{g}}$$

Now, the acceleration of the system is just

$$a = \frac{m}{m + M}\, g$$

where ***m*** is the hanging mass and ***M*** is the mass of the cart and all attachments including the ball. Substituting this value for acceleration into the equation for ***x*** gives us our desired equation:

$$x = 2\sqrt{\frac{mdy}{m + M}}$$

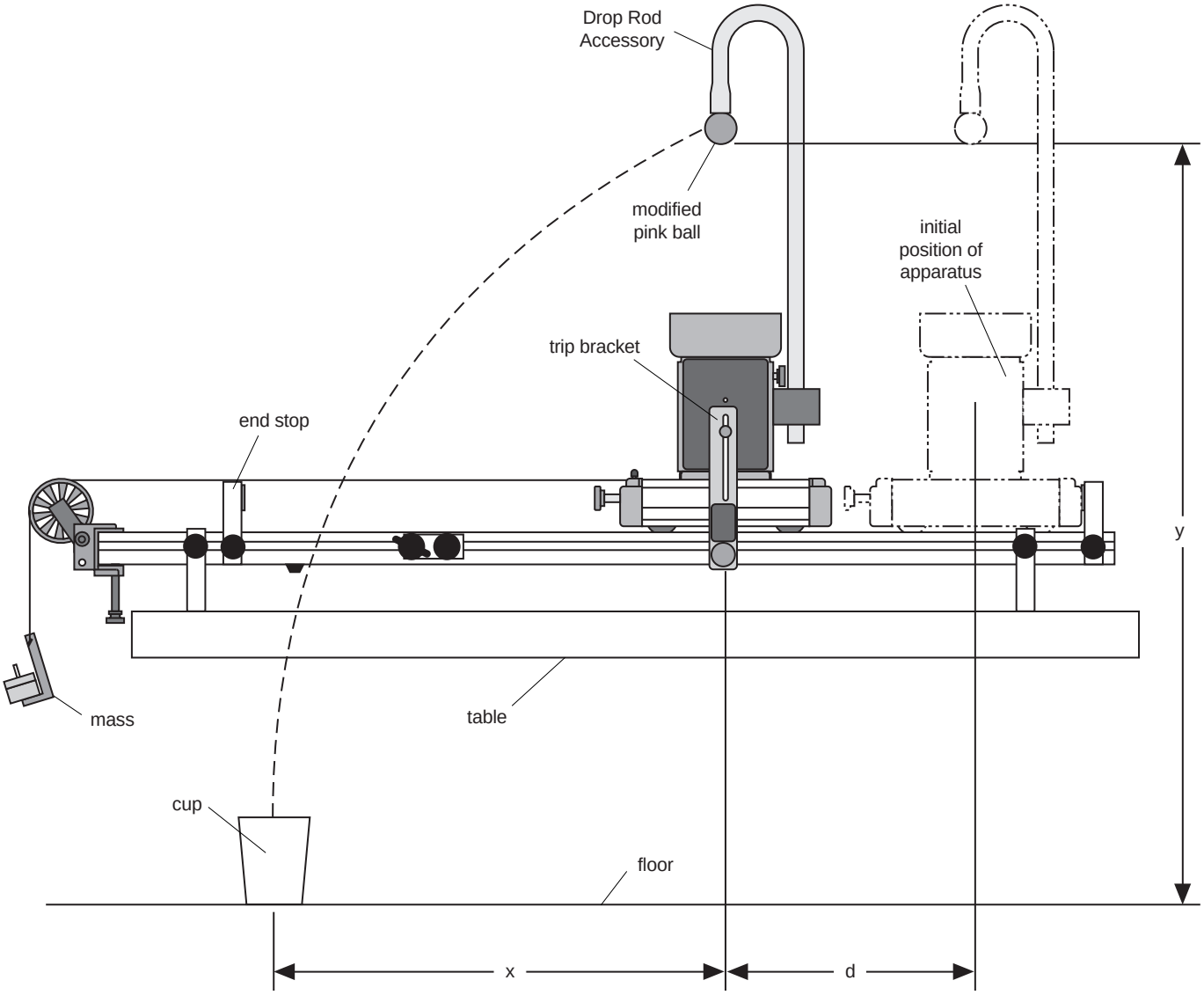


Figure 9.2: Projectile Motion For Bombing Run.

Procedure

① Weigh the cart and its attachments. Record this mass as M. Weigh the hanging mass, and record it as m.

② Set up the equipment as shown in Figure 10.1. You may want to tape a large sheet of paper to the floor on which to mark positions.

③ Hold the cart in its initial position against the end stop. Hang the plumb bob from the ball release point and mark the initial position. Slowly move the cart to where the trip bracket just causes the ball to release, and use the plumb bob to mark this position. Measure the distance between these positions and record as d.

④ Calculate x. Measure this distance from the point at which the ball drops, and mark this location. Place the paper cup on this mark.

⑤ Hold the cart against the end stop. Make sure that the ball is loaded correctly and the Ballistic Cart Accessory is turned on.

⑦ Release the cart, and see if the ball lands in the cup.

Questions

① Did the ball land in the cup? If not, why not?

② What are some of the possible sources of error in this experiment that would cause the ball to miss?

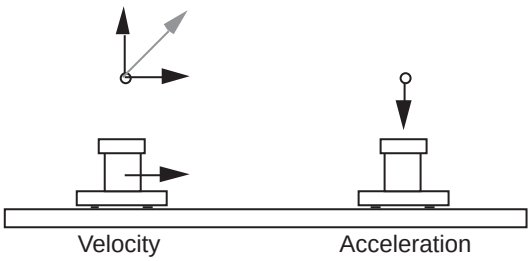
Teacher's Guide

Experiments 4 and 7: Inclined Plane - Demonstration

Why the Ball is Still Caught in the Inclined Plane Experiments

There have been enough questions about these two experiments—including some from people who should know better—that we thought it would be best to explain exactly what was going on and why the ball is still caught.

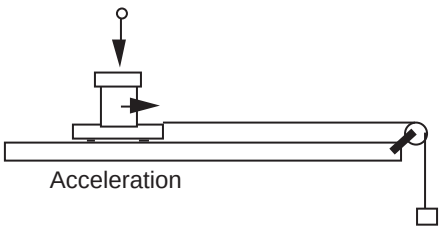
First, let's consider the horizontal case:



The cart and the ball have the same horizontal component of velocity. The vertical component of the ball's velocity does not affect the alignment of the ball and cart, so the ball lands in the cart.

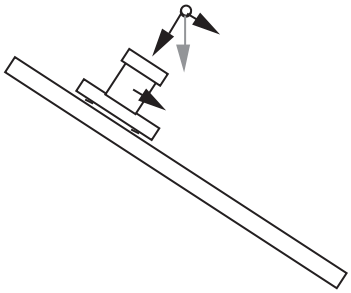
The horizontal component of the acceleration of both cart and ball is the same: zero, which ensures that the ball and cart remain aligned.

Now let's consider the case where the cart is accelerating:



In this case, the ball's acceleration is still only in the vertical plane, but the cart has a horizontal acceleration. This horizontal acceleration changes the velocity of the cart, but not the velocity of the ball. The cart does not remain directly beneath the ball and the ball is not caught.

When the track is tilted, things become a bit more complicated; but if you break the vectors into their components it becomes more clear:



The cart and the ball have the same component of acceleration parallel to the track. Since they have the same *initial* parallel-component velocity and the same acceleration, they will thus *always* have the same parallel-component velocity. The ball will always be on a line with the cart perpendicular to the track, and it will be caught.

Technical Support

Feed-Back

If you have any comments about this product or this manual please let us know. If you have any suggestions on alternate experiments or find a problem in the manual please tell us. PASCO appreciates any customer feed-back. Your input helps us evaluate and improve our product.

To Reach PASCO

For Technical Support call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

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Before you call the PASCO Technical Support staff it would be helpful to prepare the following information:

- If your problem is computer/software related, note:

  Title and Revision Date of software.

  Type of Computer (Make, Model, Speed).

  Type of external Cables/Peripherals.

- If your problem is with the PASCO apparatus, note:

  Title and Model number (usually listed on the label).

  Approximate age of apparatus.

  A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.)

  If possible, have the apparatus within reach when calling. This makes descriptions of individual parts much easier.

- If your problem relates to the instruction manual, note:

  Part number and Revision (listed by month and year on the front cover).

  Have the manual at hand to discuss your questions.