Interactive Lecture Demonstrations

Active Learning in Introductory Physics

THE PHYSICS SUITE

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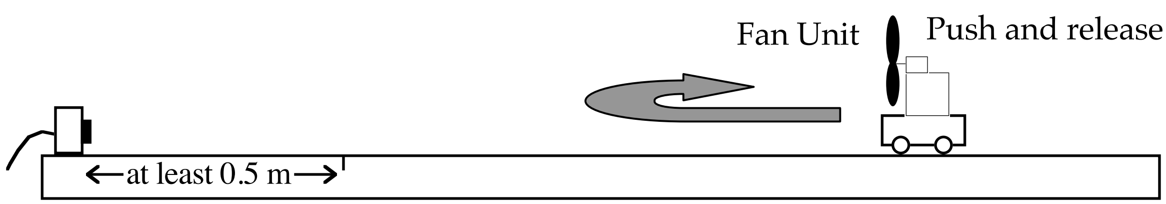
RONALD K. THORNTON

INTERACTIVE LECTURE DEMONSTRATIONS

<u>Demonstration 6:</u> Cart moves toward the motion detector and slows down then reverses direction and speeds up.



Prediction begins just after cart leaves hand and ends just before the cart is stopped.

(Ask students to pay particular attention to the point where it turns around.)

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University of Oregon

Ronald K. Thornton The Center for Science and Math Teaching

Departments of Physics and of Education

Tufts University

Acknowledgements:

We are especially grateful to Priscilla Laws of Dickinson College for her continuing collaboration that has contributed significantly to this work. We thank Jeff Marx, Shawn Kolitch and Dennis Kuhl for their contributions of ideas for *ILD* sequences, and the many college and high school faculty—including them—who have classroom tested *ILDs* over the years. The curricula that we have developed would not have been possible without the hardware and software development work of Stephen Beardslee, Lars Travers, Ronald Budworth and David Vernier. We also thank the physics faculty and students at the University of Oregon and Tufts University for participating in the *ILDs* and learning assessments.

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This work was supported in part by the National Science Foundation and the Fund for Improvement of Post-secondary Education (FIPSE) of the U.S. Department of Education. Opinions expressed are those of the authors and not necessarily those of these agencies.

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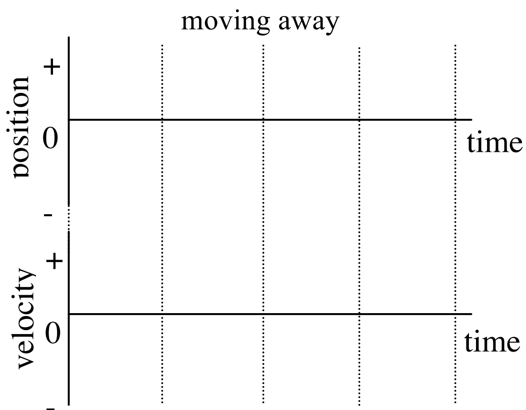
Hand in this sheet **Name______________________________**

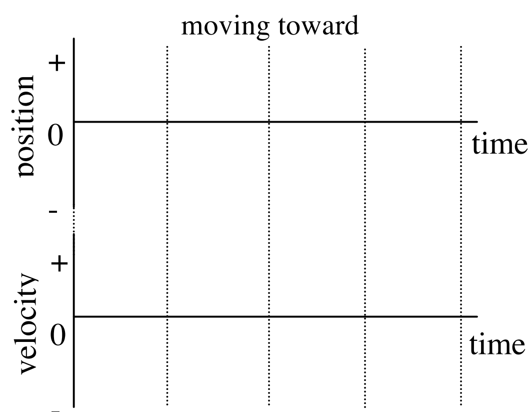
INTERACTIVE LECTURE DEMONSTRATIONS

PREDICTION SHEET—**KINEMATICS 2—MOTION OF CARTS**

Directions: This sheet will be collected. Write your name at the top to record your presence and participation in these demonstrations. Follow your instructor's directions. You may write whatever you wish on the attached Results Sheet and take it with you.

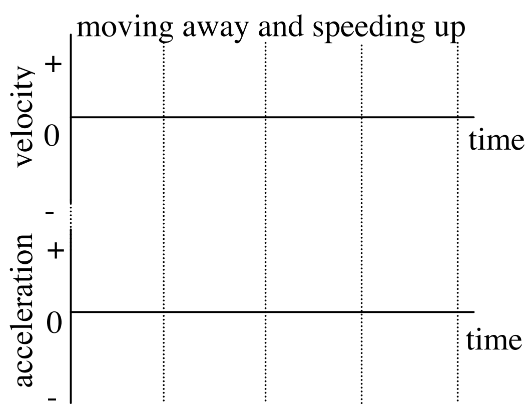
Demonstration 1: On the left velocity axes below sketch your prediction of the *velocity-time* graph of the cart moving away from the motion detector at a steady (constant) velocity. On the left position axes below sketch your prediction of the *position-time* graph for the same motion.



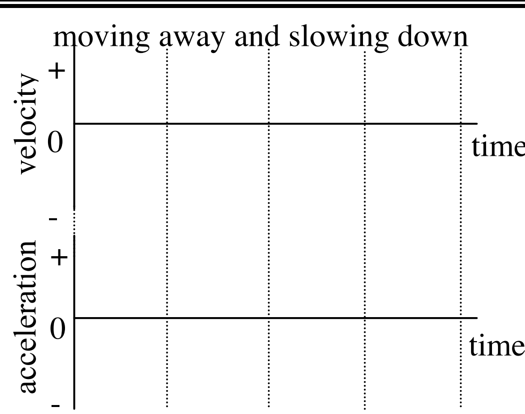


Demonstration 2: On the right velocity axes above sketch your prediction of the *velocity-time* graph for the cart moving toward the motion detector at a steady (constant) velocity. On the right position axes above sketch your prediction of the *position-time* graph for the same motion.

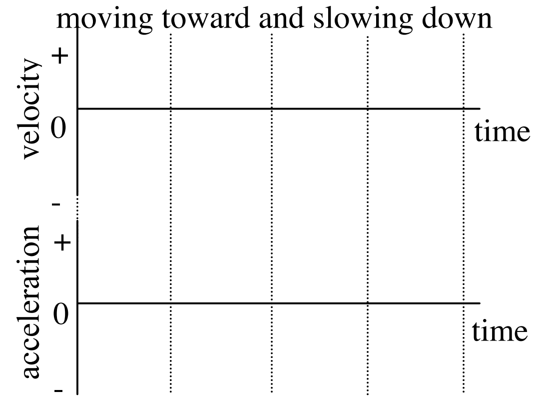
Demonstration 3: Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the cart moving away from the motion detector and speeding up at a steady rate.



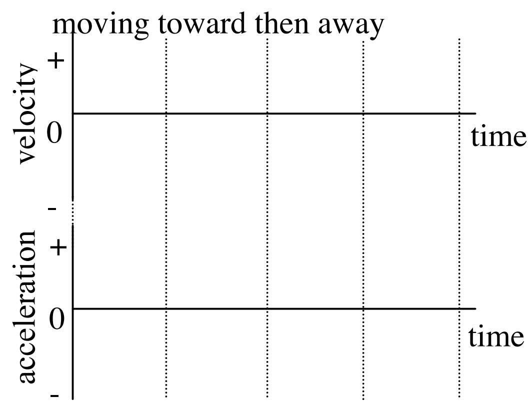
Demonstration 4: Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the cart moving away from the motion detector and slowing down at a steady rate.



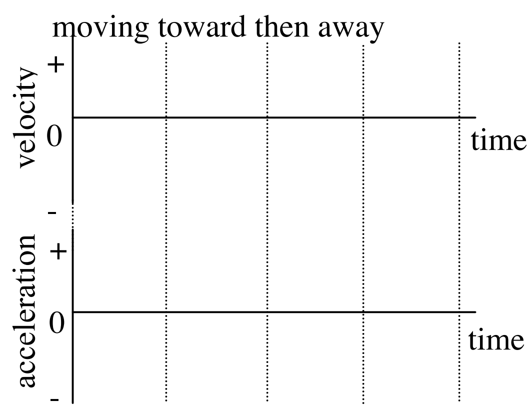
Demonstration 5: A cart is subjected to a constant force in the direction away from the motion detector. Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the cart moving toward the motion detector and slowing down at a steady rate. (Start your graph after the push that gets the cart moving.)



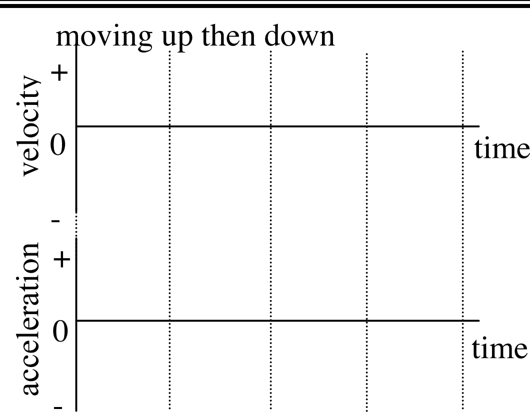
Demonstration 6: A cart is subjected to a constant force in the direction away from the motion detector. Sketch on the axes on the right your predictions of the *velocity-time* and *acceleration-time* graphs of the cart after it is given a short push toward the motion detector (and is released). Sketch velocity and acceleration as the cart slows down moving toward the detector, comes *momentarily* to rest and then speeds up moving away from the detector.



Demonstration 7: Sketch below your predictions for the *velocity-time* and *acceleration-time* graphs for the cart which is given a short push up the inclined ramp toward the motion detector (and is released) Sketch the graph as the cart slows down moving toward the detector, comes *momentarily* to rest and then speeds up moving away from the detector.



Demonstration 8: The origin of the coordinate system is on the floor, and the positive direction is upward. A ball is thrown upward. It moves upward, slowing down, reaches its highest point and falls back downward speeding up as it falls. Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the ball from the moment just after it is released until the moment just before it hits the floor.

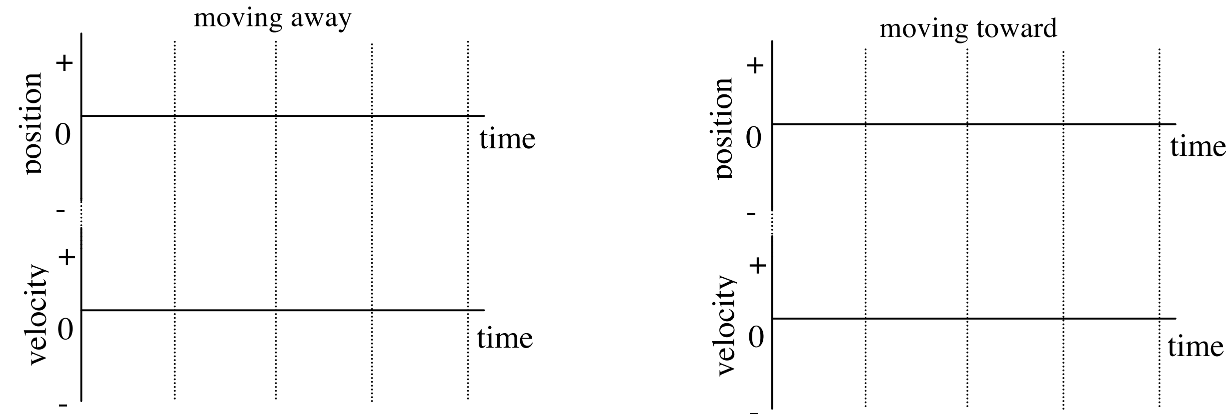


Keep this sheet

INTERACTIVE LECTURE DEMONSTRATIONS
RESULTS SHEET—**KINEMATICS 2—MOTION OF CARTS**

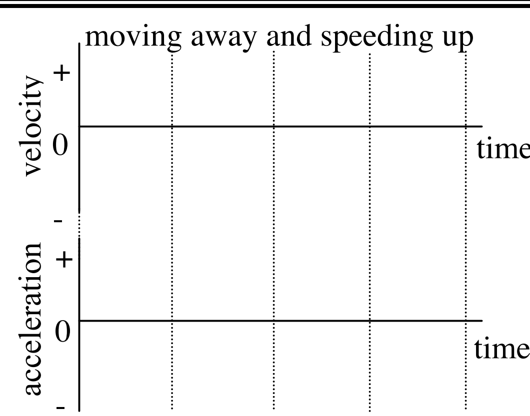
You may write whatever you wish on this sheet and take it with you.

Demonstration 1: On the left velocity axes below sketch your prediction of the *velocity-time* graph of the cart moving away from the motion detector at a steady (constant) velocity. On the left position axes below sketch your prediction of the *position-time* graph for the same motion.



Demonstration 2: On the right velocity axes above sketch your prediction of the *velocity-time* graph for the cart moving toward the motion detector at a steady (constant) velocity. On the right position axes above sketch your prediction of the *position-time* graph for the same motion.

Demonstration 3: Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the cart moving away from the motion detector and speeding up at a steady rate.



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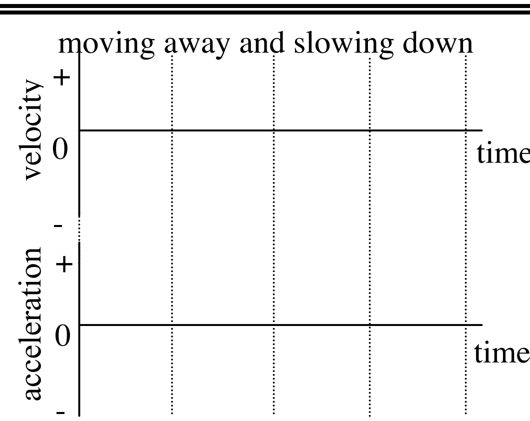
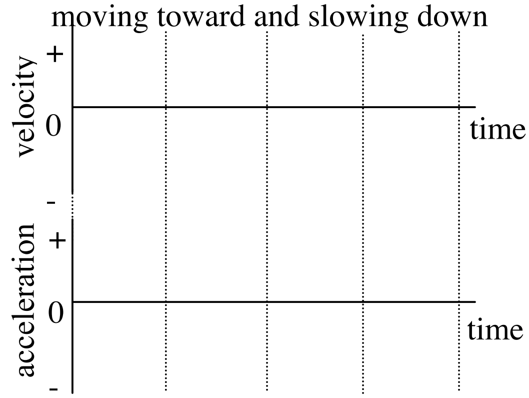
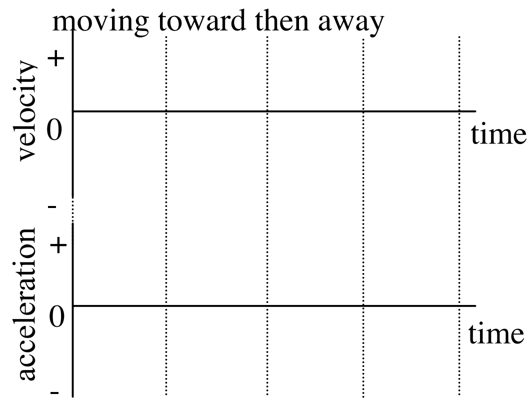


Demonstration 5: A cart is subjected to a constant force in the direction away from the motion detector. Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the cart moving toward the motion detector and slowing down at a steady rate. (Start your graph after the push that gets the cart moving.)



Demonstration 6: A cart is subjected to a constant force in the direction away from the motion detector. Sketch on the axes on the right your predictions of the *velocity-time* and *acceleration-time* graphs of the cart after it is given a short push toward the motion detector (and is released). Sketch velocity and acceleration as the cart slows down moving toward the detector, comes *momentarily* to rest and then speeds up moving away from the detector.



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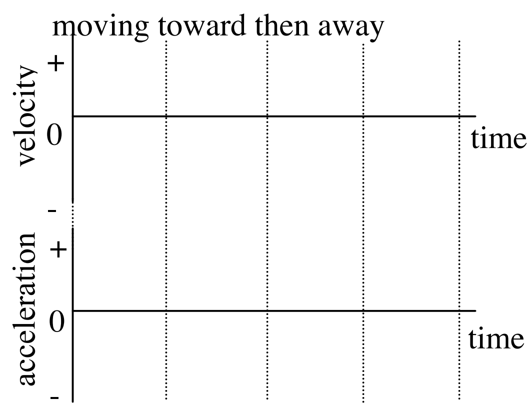
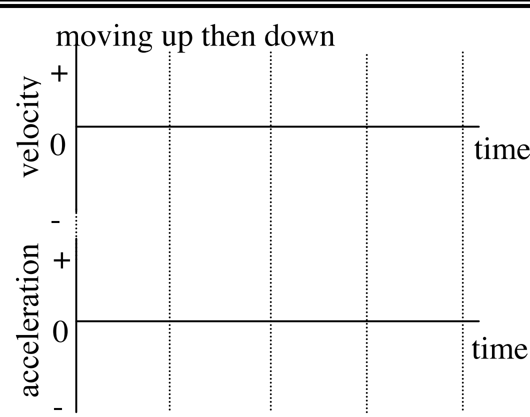


Demonstration 8: The origin of the coordinate system is on the floor, and the positive direction is upward. A ball is thrown upward. It moves upward, slowing down, reaches its highest point and falls back downward speeding up as it falls. Sketch on the axes on the right your predictions for the *velocity-time* and *acceleration-time* graphs of the ball from the moment just after it is released until the moment just before it hits the floor.



KINEMATICS 2—MOTION OF CARTS (KIN2)
TEACHER'S GUIDE

Prerequisites:

The *Kinematics 1—Human Motion ILD* sequence is the only prerequisite. If your students have done *RealTime Physics Mechanics* Lab 1 or *Tools for Scientific Thinking Motion and Force* Lab 1, you can skip the *Human Motion ILDs,* and go directly into *Motion of Carts.* We have found the *Motion of Carts ILDs* to be a useful review even for students who have completed the first two kinematics labs in the above laboratory modules.

Equipment:

computer-based laboratory system

ILD experiment configuration files

motion detector (one is okay but two are better, since one will need to be mounted on the ceiling)

two low-friction kinematics carts are better, one with the fan unit pre-mounted (If you only have one, you can mount the fan unit during the demonstrations. Any cart with very low friction will work but truly low friction carts are difficult to find.) (See below.)

fan unit (See below.)

2.2 meter aluminum track, long door threshold or a very smooth, level table or ramp (See below.)

basketball or other large round ball (Tennis balls do not work well due to the fury covering and soccer balls are not round.)

General Notes on Preparation and Equipment:

Low friction carts:
In order to get the smoothest possible acceleration graphs, considerable care must be taken in choosing a cart and a ramp. The cart must have smooth wheels that do not rub or bind. The best results are obtained by using dynamics carts with roller bearing wheels such as the PASCO ME-9430, ME-9454, ME-6950 or ME-6951. The PASCO carts have very little friction and are very sturdy. One additional advantage is that there is a Friction Cart Accessory Kit (ME-9457) available that converts the PASCO low friction cart to a cart with adjustable friction.

Track or ramp:
This laboratory does not strictly need a ramp except for Demonstration 7 since all other demonstrations are done on a level surface. (Even Demonstration 7 could be done with a suitable table that could be tilted.) A table top with a very smooth surface (e.g., Formica) and a clear distance of about 2 meters (with no cracks) will work just fine. However, most tables are too short or have too many nicks and scratches. Pushing two tables together won't work because of the crack in the middle.

An additional advantage to having a ramp is that it can be easily elevated to provide a longer falling distance for the hanging mass in the modified Atwood's machine for the *Newton's 1st & 2nd Laws ILDs.*

A 2.2 m Dynamics Track with grooves for the cart is available from PASCO (ME-9458 or ME-9453). If you choose to purchase PASCO (www.pasco.com) carts, this track is ideal but expensive. (Note that the 1.2 m Dynamics Track (ME-9435A) and the 1.2 m Force and Motion Track (ME-6858) are both too short for these demonstrations.

If instead you choose to build your own ramp, there are several options. A 2-2.5 m door threshold, available from most building supply or door and window stores, works very well, and is much less expensive than the PASCO tracks. It is not necessary for the grooves to match up with the spacing between the wheels on the cart. In fact, the wheels may bind if the grooves are narrow and exactly matched to the spacing. It is better for the cart to ride in just one groove. Since a threshold is somewhat flexible, it will need to be placed on a flat, level table or mounted on a flat board.

It is also possible to fabricate a wooden ramp. It should be about 2.2 m long and 20 - 30 cm wide, with a very smooth top surface. A design that works well uses 3/4" plywood with one side furniture grade. Cut one 12" wide strip about 8' long and two 2" strips to glue and screw edgewise to the 12" strip. Without these strips, the plywood will bow too much when supported at two points. Glue plastic coated paneling or Formica on the board to provide a smooth surface for the carts. The design is shown in Figure II-3.

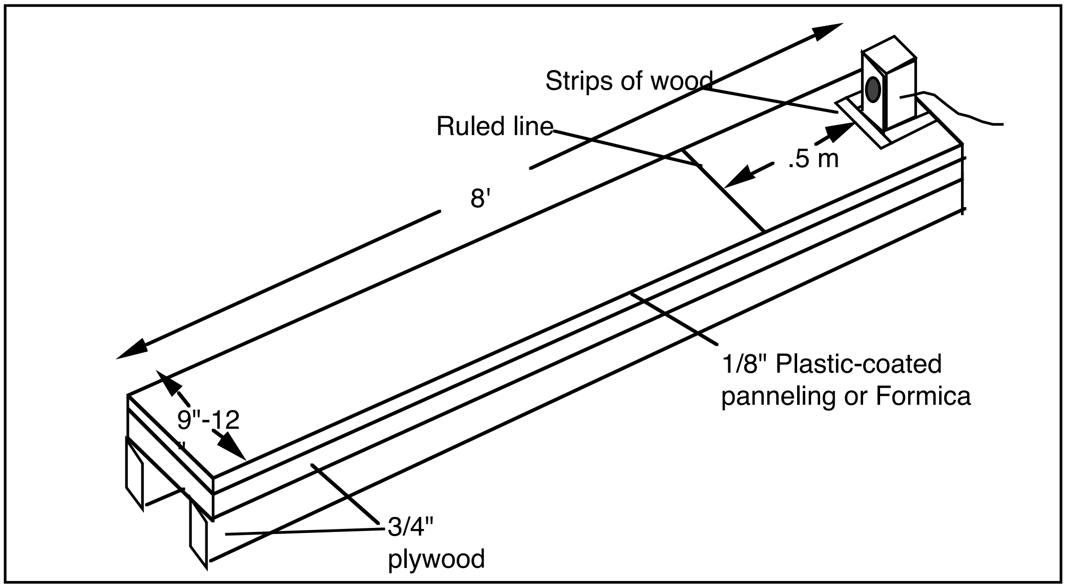


Figure II-3. A suggested ramp construction

You may also build a small holder for the motion detector at one end, and mark a line across the width of the board, 0.5 m from the detector.

Fan unit:
A fan unit is available from PASCO that mounts on any of the PASCO carts listed above (Fan Accessory—ME-9491).

It is also possible to construct fan units for use with the PASCO carts. The design described below and pictured in Figure II-4 is adapted from Robert Morse's design in his October, 1993 paper in *The Physics Teacher* (vol. 31, pp. 336-438). A later design can be found on the Workshop Physics web site at http://physics.dickinson.edu.

You will need the following major parts for each fan unit:

- 6.5 cm long piece of 6.5 cm cross-section PVC downspout
- DC motor with a no-load speed of about 8000 rpm (Radio Shack #273-223 works)
- 12.5 cm nylon propeller (e.g., #858 from Cox Hobbies, Corona, CA)
- Battery holder for 4 AA batteries (e.g., Radio Shack #270-391)
- SPST push-button switch (e.g., Radio Shack #275-1565). (Substituting a DPDT switch will make it possible to reverse the thrust of the fan unit. Adding a potentiometer will provide an adjustable acceleration.)

Figure II-4: Photograph of homemade fan unit mounted on a PASCO cart.

Cut one side off the downspout, leaving a U-shaped piece that will grasp onto the top of the PASCO cart. (When in use, the fan unit should always be taped onto the cart or held on with a rubber band. This precaution will prevent it from flying off when the cart is brought to a sudden stop, such as by colliding with a bumper.) The motor is fastened to the top of the PVC section, and the switch is inserted in a hole drilled through the top. The battery holder is fastened to the side with self-tapping sheet metal screws. Finally, the most difficult problem is fastening the propeller to the motor shaft. The best, most permanent solution is to machine a piece of metal with a hole and set screw on one end to fasten to the motor shaft and a threaded hole on the other end for fastening the propeller with a machine screw. This is labor intensive, but we have not found a satisfactory method of gluing or pressure-fitting the propeller to the motor shaft.

Rechargeable batteries are very convenient for any model fan unit.

Great care should be taken to keep fingers away from the propeller. Nicks caused by sticking a finger in the path of the blade are painful, but not particularly dangerous. It is also important to keep the fan units from falling on the floor. The impact can bend the brushes in the motor and stop it from working.

A Fan Cart is available from PASCO (ME-9485). The cart has the same low friction wheels as the PASCO dynamics cart. However, the fan cart does not have collision bumpers or a friction pad assembly, and may not be as convenient for other standard experiments (e.g., collisions) as a dynamics cart. It does not allow easy mounting of a force probe for later dynamics demonstrations.

Substitute for fan unit:
A modified Atwood's machine (pulley and falling mass) can be used in place of the fan unit, and works quite well, although acceleration by a fan unit is more transparent to most students. (See the Teacher’s

Guide for the *Newton's 1st & 2nd Laws ILDs*, page 54. It is important in this case to provide at least a 1.5 m distance for the mass to fall by elevating the ramp or using two pulleys. Elevating the ramp and using one pulley is better because of the difficulties in aligning two pulleys.)

Experimental setup:
We elevate a PASCO 2.2 m track on a rolling table so it can be easily seen by the class, and check to see that the track is level when the table is in demonstration position.

As you practice the following *ILDs*, remember that for many motion detectors the cart must never be closer than 0.5 m.

For Demonstration 8, it is easiest to mount the motion detector on the ceiling and throw the ball up toward the motion detector. (The experiment configuration file is set so that the upward direction (toward the motion detector) is positive.) In this configuration you are less likely to put your hands between the ball and the motion detector, and it is easier to keep the ball in view of the motion detector. (This also eliminates the need for a screen to protect a motion detector on the floor.) It still takes some practice to get good graphs. The hardest part is keeping hands and other body parts out of the view of the motion detector. Be sure that the motion detector is seeing the ball.

Demonstrations and Sample Graphs:

We suggest you work through the demonstrations before you do them for the class making use of the suggestions below and comparing your results to those shown. Work out any difficulties and be sure the experiment configuration files display well with your equipment.

Demonstration 1: Cart moves away from motion detector at constant velocity. (Use experiment configuration file **KIN2D1**.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.

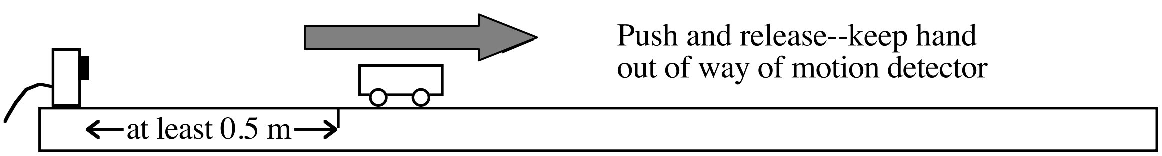


Figure II-5 shows typical position-time and velocity-time graphs. Figure II-6 shows the acceleration-

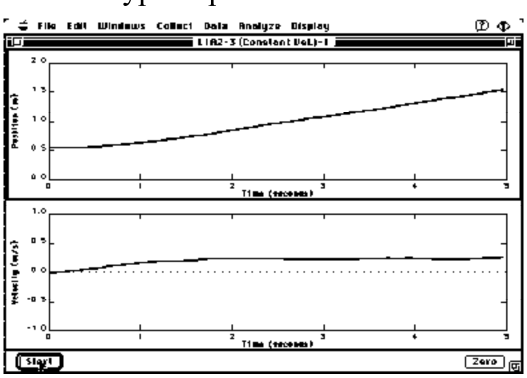


Figure II-5: Position-time and velocity-time graphsfor a cart moving away from the motion detector at a constant velocity.

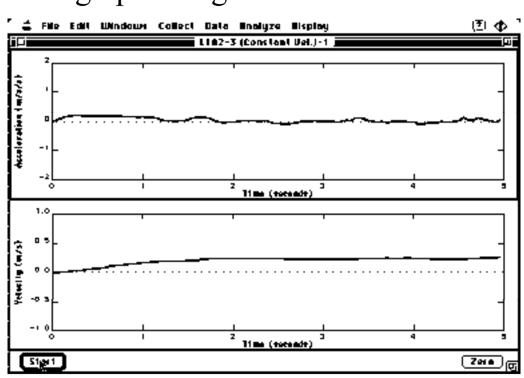


Figure II-6: Acceleration-time and velocity- time graphs for the same motion as in Figure II-5.

time and velocity-time graphs for the same motion of the cart.

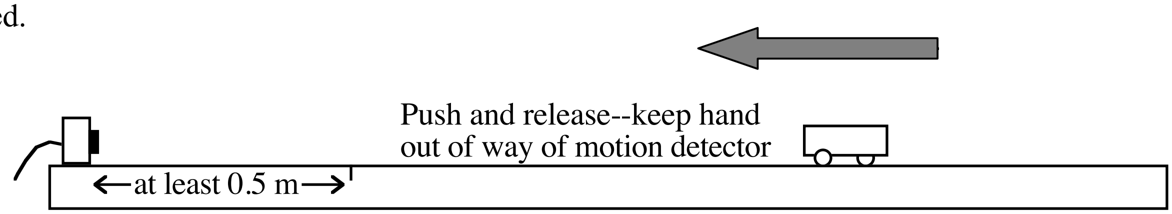
If your velocity and acceleration graphs are much bumpier than these, check your experimental setup. See the suggestions under Demonstration 3.

Discussion after the graphs are displayed: The velocity is in the positive direction. The position-time and velocity-time graphs are the same as for walking away from the motion detector at a constant velocity in the *Human Motion ILDs*.

Constant velocity means acceleration is essentially zero. (A small amount of friction may be evident, but students generally don't even notice it.) Discuss the slope of a position-time graph and its relationship to the velocity.

After the discussion, these graphs should be saved for persistent display on the screen and then hidden.

__Demonstration 2:__ **Cart moves toward the motion detector at a constant velocity.** (Use experiment the same configuration file.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.



Again, if your velocity and acceleration graphs are much bumpier than those in Figures II-5 and II-6, check your experimental setup. See the suggestions under Demonstration 3.

Discussion after the graphs are displayed: The velocity is in the negative direction. Constant velocity means acceleration is essentially zero. (A small amount of friction may be evident.) Discuss slope of position-time graph and relationship to velocity. Show the graphs from Demonstration 1 and compare them.

__Demonstration 3:__ **Cart moves away from the motion detector and speeds up at a steady rate.** (Use experiment configuration file **KIN2D3**.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.

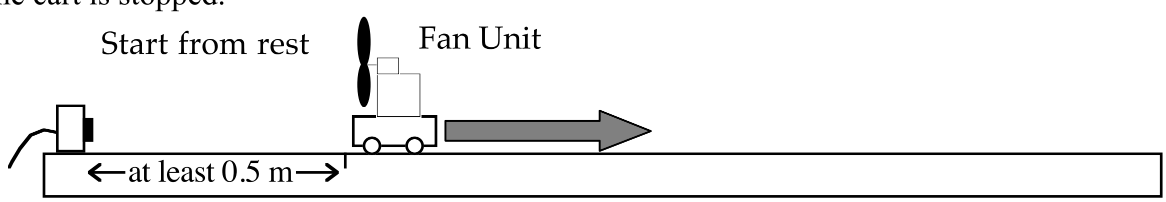


Figure II-7 shows typical graphs of position-time, velocity-time and acceleration-time graphs.

__Troubleshooting your graphs:__ If your position-time graph levels off and the velocity and acceleration fall to zero at the same instant, then the motion detector is likely seeing something other than the cart. Read the position-time graph to locate the position of this object, and move it or tilt the motion detector slightly away from it.

If your velocity-time and especially your acceleration-time graphs are bumpier than those in Figure II-7, several things might be wrong:

1. The track is not smooth, and the bumps represent real characteristics of the motion of the cart.
2. The bearings of the cart's wheels are bad, and they are causing the acceleration to be non-constant.

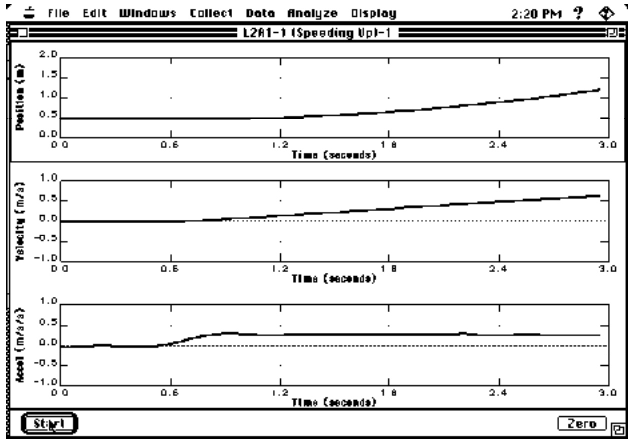


Figure II-7: Position-time, velocity-time and acceleration-time graphs for a low-friction cart with a fan unit moving away from the motion detector with a constant acceleration as in Demonstration 3.

3. The fan blade is extending beyond the end of the cart, and the motion detector is intermittently seeing the fan blade and the cart.
4. If the acceleration is okay for part of the run but varies as the cart moves away, the detector may be at an angle and shifting from one part of the cart to another. Adjusting the detector may improve things.
5. The motion detector, interface or cables may be too close to an electronically noisy monitor. Try moving the monitor further away

If you have eliminated (1) - (5), and the graphs are still bumpy, try taping a stiff piece of cardboard a few inches high to the end of the cart facing the motion detector to act as a reflector. This should improve the graphs but is ordinarily not necessary.

Discussion after the graphs are displayed: Note that the velocity is a straight line with positive slope. Velocity increasing steadily means that the acceleration is positive and constant.

<u>**Demonstration 4:**</u> **Cart moves away from the motion detector and slows down at a steady rate (fan opposed to the push).** (Use experiment configuration file **KIN2D4**.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.

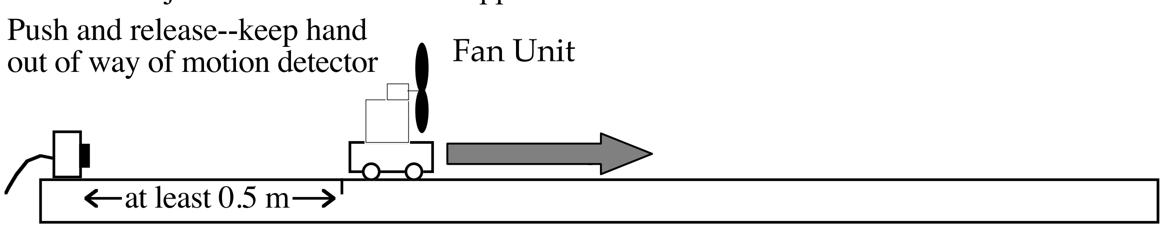


Figure II-8 shows typical velocity-time and acceleration-time.

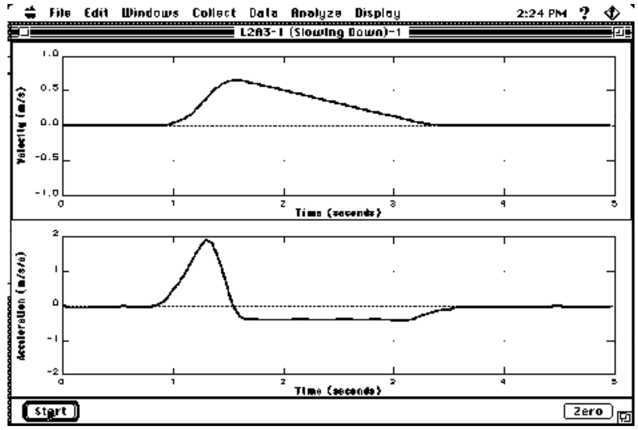
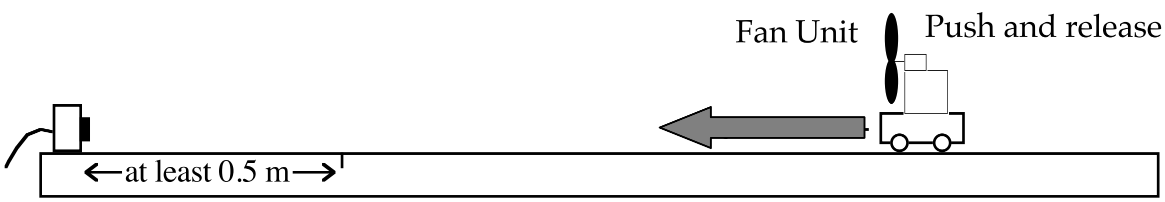


Figure II-8: Velocity-time and acceleration-time graphs for a low-friction cart with a fan unit moving away from the motion detector and slowing down at a steady rate as in Demonstration 4.

Discussion after the graphs are displayed: Select the relevant portions of the graphs. The velocity is decreasing (straight line with negative slope) although the velocity is always positive. The acceleration is in the opposite direction to the velocity so it must be negative. Since the cart is slowing down at a steady rate, the acceleration is negative and constant.

<u>Demonstration 5:</u> **Cart moves toward the motion detector and slows down at a steady rate (fan opposes push).** (Use the same experiment configuration file as in Demonstration 3.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.

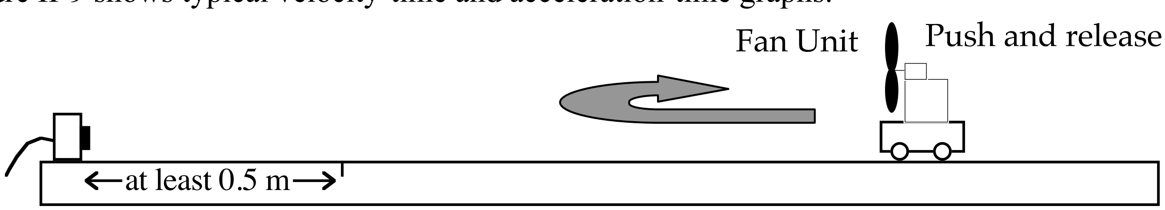


Cart is slowing down so velocity begins as large negative number and becomes smaller negative number.

Discussion after the graphs are displayed: The velocity is in the negative direction. (The cart is slowing down, so the velocity begins as large negative number and becomes smaller negative number.) Note that the acceleration is positive even though the cart is slowing down. *Deceleration* is not necessarily *negative* acceleration. Sign just shows the direction. Whenever the acceleration is in the direction opposite to velocity, the cart is slowing down. When acceleration and velocity are in the same direction, the cart speeds up. It is probably best to avoid the word *deceleration*.

<u>Demonstration 6:</u> **Cart moves toward the motion detector and slows down, then reverses direction and speeds up.** (Use experiment configuration file **KIN2D6**.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.

Figure II-9 shows typical velocity-time and acceleration-time graphs.



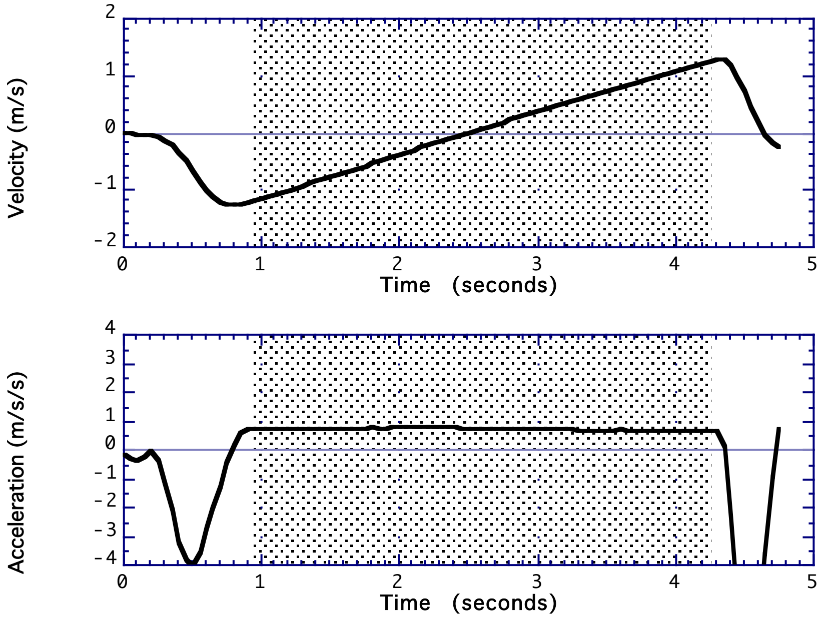


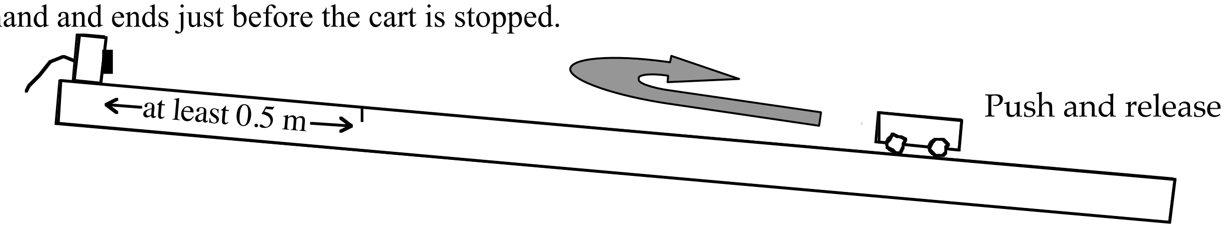
Figure II-9: Actual data from Demonstration 6 in which a cart with a fan unit opposing the initial motion was given a quick push toward the motion detector. The part of the motion that the students were asked to predict is selected just as you should do in class.

When you push the cart toward the detector, be sure it doesn't come closer than 0.5 m or you could end up with a false display of zero velocity for an extended period at the top of the motion. Since acceleration will also be displayed falsely as zero, you must avoid this at all costs or you will reinforce the standard student belief.

Discussion after the graphs are displayed: Pay particular attention to the point where the cart reverses direction, and have students explain why the velocity is zero but the acceleration isn't. The acceleration can be described as the slope of the velocity time graph at this point (positive and constant). Or, it can be calculated as the rate of change of velocity with time, requiring two different velocities for the calculation. Only one of these velocities is zero. Explain the sign and direction of the acceleration.

If the cart has substantial friction you may see different slopes on the velocity graph and also different values of the acceleration for motion of the cart toward and away from the motion detector. Try to avoid this result even though it is interesting and could be demonstrated later with substantial friction. If you discuss this now, you may fail to get the main point across which is that the acceleration is constant (does not go to zero as the cart turns around) and the velocity (consequently) is a straight line with positive slope across zero.

<u>**Demonstration 7:**</u> **Cart moves up inclined ramp, reaches highest point, and rolls back down.** (Use the same experiment configuration file as in Demonstration 6.) Prediction begins just after cart leaves hand and ends just before the cart is stopped.



The velocity-time and acceleration-time graphs for this motion should resemble those for Demonstration 6, shown in Figure II-9.

Discussion after the graphs are displayed: Discuss analogies with previous demonstration and with the coin toss. (Again, direct student attention to the point where the cart reversed direction.) As in Demonstration 6, if the cart has substantial friction you may see different slopes on the velocity graph and also different values of the acceleration for motion of the cart on the way up and on the way down.

<u>Demonstration 8:</u> **A ball is thrown straight upward, reaches its highest point, and comes back down.** (Use experiment configuration file **KIN2D8**. The origin is set to be on the floor with the positive direction upward even though motion detector is best mounted on the ceiling. (See the discussion under **Experimental setup**.) Figure II-10 shows typical velocity-time and acceleration-time. You can see the throw and the ball hitting the floor in the acceleration graph.

The data collection rate has been set at 30 points per second. Still the number of data points collected before the ball hits the floor is small. You might try a larger data rate--50 points per second, but this can give spurious data because of multiple reflections of the ultrasound pulses between the motion detector and the floor. A carpeted floor or a cloth under the motion detector can make this effect less likely.

Discussion after the graphs are displayed: Discuss analogies with previous demonstration. Ask what is the same (constant force initially opposing the motion) and what is different (much larger force). (Again, direct student attention to the point where the ball reversed direction.)

Note: Demonstrations 6, 7 and 8 may seem repetitive, but our research shows that all of these are necessary for students to learn the concepts.

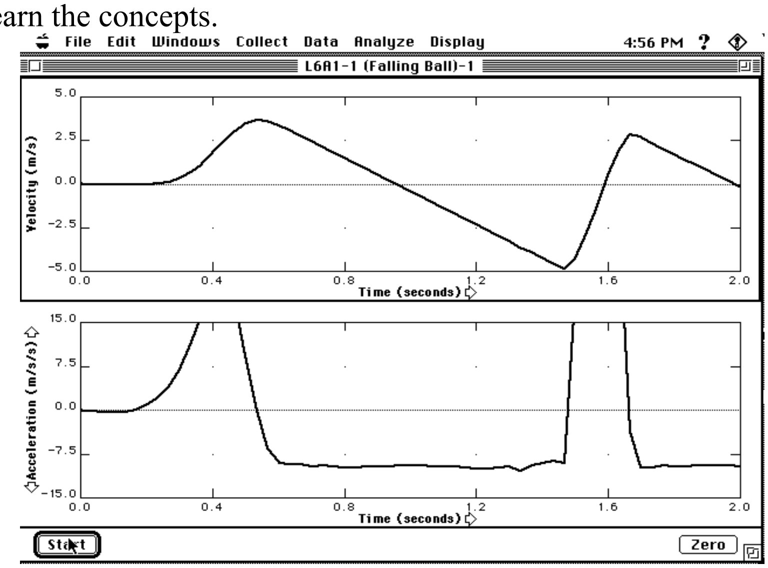


Figure II-10: Velocity-time and acceleration-time graphs for Demonstration 8 for a basketball thrown up toward the motion detector and allowed to move upward, reverse direction and fall back down again. The origin has been set to be at the floor rather than at the motion detector on the ceiling.

KINEMATICS 2—MOTION OF CARTS (KIN2)
TEACHER PRESENTATION NOTES

Classroom introduction to the *Accelerated Motion ILDs*:
Students should be familiar with the motion detector from the *Human Motion ILDs.* Push a wood block on the track or a book on the table (without measurement) to show students the motion with friction that they are accustomed to seeing where objects stop moving when they are not pushed. Emphasize the point that the cart you are using has very low friction.

<u>**Demonstration 1:**</u> **Cart moves away from motion detector at a constant velocity.** Use experiment configuration file **KIN2D1**. Prediction from just after cart leaves hand to just before the cart is stopped.

- Velocity is in positive direction.
- Constant velocity means acceleration is essentially zero.
- Discuss slope of position-time graph.
- After discussion save data to display graphs persistently and then hide them.

<u>**Demonstration 2:**</u> **Cart moves toward the motion detector at a constant velocity.** Use same experiment configuration file as in Demonstration 1. Prediction from just after cart leaves hand to just before the cart is stopped.

- Velocity is in negative direction.
- Constant velocity means acceleration is essentially zero.
- Discuss slope of position-time graph.
- Compare to Demonstration 1 by showing stored data.

<u>**Demonstration 3:**</u> **Cart moves away from the motion detector and speeds up at a steady rate.** Use experiment configuration file **KIN2D3**. Prediction from just after cart leaves hand to just before the cart is stopped.

- Velocity is straight line with positive slope.
- Velocity increasing steadily means acceleration is positive and constant.

<u>**Demonstration 4:**</u> **Cart moves away from the motion detector and slows down at a steady rate (fan opposed to push).** Use experiment configuration file **KIN2D4**. Prediction from just after cart leaves hand to just before the cart is stopped.

- Velocity is decreasing (straight line with negative slope) although velocity is always positive.
- Acceleration has opposite direction to velocity. It is negative and constant.

<u>**Demonstration 5:**</u> **Cart moves toward the motion detector and slows down at a steady rate (fan opposed to push).** Use same experiment configuration file as in Demonstration 3. Prediction from just after cart leaves hand to just before the cart is stopped.

- Velocity in negative direction. (Cart is slowing down so velocity begins as large negative number and becomes smaller negative number.)
- Note that acceleration is positive even though cart is slowing down. When acceleration is in direction opposite to velocity, the cart is slowing down. When acceleration and velocity are in the same direction, cart speeds up.

<u>**Demonstration 6:**</u> **Cart moves toward the motion detector and slows down then reverses direction and speeds up.** Use experiment configuration file **KIN2D6**. Prediction from just after cart leaves hand to just before the cart is stopped.

- Pay particular attention to the point where cart reverses direction and have students explain why velocity is zero but acceleration isn't.
- Explain direction of acceleration.

Demonstration 7: **Cart moves up inclined ramp, reaches highest point, and rolls back down.** Use same experiment configuration file as in Demonstration 6. Prediction from just after cart leaves hand to just before the cart is stopped.

- Discuss analogies with previous demonstration and with the coin toss.
- Again, direct student attention to the point where cart reversed direction.

Demonstration 8: **A ball is thrown straight upward, reaches its highest point, and comes back down. .** Use experiment configuration file **KIN2D8**. Prediction from just after ball leaves hand to just before the ball is stopped or hits floor.

- Discuss analogies with previous demonstration.
- Ask what is the same (constant force initially opposing the motion) and what is different (much larger force, ball initially moves in positive direction).
- Again, direct student attention to the point where the ball reversed direction.