Chapter 7: The Movie Collection

7. The Movie Collection

7.1 Introduction to the Movies

Uses for the Collection

We know that many VideoPoint users will want to take their own movies or create digital movies from the wealth of available analog materials. However, we discovered that it is very helpful to have a collection of movies to available to use with VideoPoint for those instances when you don't have enough time, the right capture equipment or enough know-how to produce all of your own movies. For these reasons, version 1 of the VideoPoint Software is bundled with a collection of over 250 short QuickTime movies.

The VideoPoint movie collection can be used to help instructors and students learn how to use VideoPoint features, do some warm-up exercises in the laboratory, complete homework assignments, perform lecture demonstrations and engage in open-ended projects. Each movie has a title screen that includes essential data needed for an analysis of the motions found in it. A data base has been created that gives important information about each of the movies. In addition, a program entitled Movie Browser has been created to allow VideoPoint users to identify, play and analyze movies of interest for learning about particular topics in physics.

Observations about the Collection

There are six sets of movies in the current collection. The first three sets of movies from PASCO scientific (160 movies), Princeton University (44 movies) and the University of Maryland (13 movies) were filmed in laboratory settings. The second three sets from Dickinson College (16 movies), NASA (4 movies) and Hersheypark (19 movies) contain real world images filmed outside of the confines of the laboratory. The movies in each set are listed in Section 7.3.

In spite of the fact that many of the laboratory-based movies were meant to be "ideal," an analysis of some of them indicates that some of the motions are not ideal. For example, in trying to demonstrate momentum conservation as a result of collisions of carts or airpucks, the alignment of the colliding objects is critical. A slight torque during a collision can cause a cart to slide along the side of its ramp or an airpuck to dig into the airtable. Also, friction can never be completely eliminated. It is essential that instructors analyze a movie that might be used with students before developing an assignment. The events that display a conservation law well, can be used when students are first learning about the concept. Later the "weakness" in a movie can be turned into a virtue, if students are asked to explore such questions as: "Assuming that momentum is always conserved, is momentum being transferred to the air table (or track) in this collision? Why or why not?"

We have included masses of objects on the title screen to allow students to verify various mathematical relationships and illuminate principles of physics. However, instructors may want, in some cases, to open the movie with MoviePlayer, the sim-

ple editing routine that comes with the QuickTime utility, and eliminate the title screen. This allows for some interesting assignments that allow students to apply conservation principles such as: "If the mass of the yellow cart is 0.520 kg, what is the mass of the green cart?"

Although, we have tried to include a large number of movies in which a fixed camera is oriented with the axis of its lens perpendicular to the plane of motion, some of the real world movies are not taken under these ideal conditions. These are intended to be used primarily for end-of-course projects to introduce interested students to some of the advanced features of VideoPoint.

7.2. How the Movies were Digitized

Overview

We wanted each QuickTime movie in the collection to play at full speed on both Macintosh computers operating under System 7 and PC computers operating under Windows. We also wanted the typical file size to be in the 300 - 700K range. Thus, to enhance the playback speed and minimize file size, we decided that each movie, when possible, should be half size (so as to occupy one quarter of a standard VGA screen) and should be compressed after digitization. We also decided to flatten each movie so it could be played back on either Mac or PC computers. Finally each movie was "assigned" to the VideoPoint software, so that opening a movie would also open VideoPoint.

We are sometimes asked why the quality of the images in the Movie Collection is not as good as that of typical television images. This is because information is lost when the image is reduced to quarter screen and compressed. In most cases there is no loss in the accuracy of the physics, so that the advantage of having digital movies that playback rapidly and don't require as much disk space to store far outweighs the disadvantages of seeing a poor image. A few of the Dickinson movies made by students are of lower quality, but the physics is still quite good and will give you a feel for how useful student movies can be. Also, we had no monitor available at Princeton University and were not able to set the field of view properly for the camera we had mounted on the ceiling. Thus, the Princeton set has movies that are smaller than quarter screen.

We found it relatively easy to make digital movies during physics classes, compress them and put them on the network for instant analysis by students. Thus, we were surprised to find that preparing the movies for collection was such a rigmarole. Although we have decided to describe the process here just for the record, it would be futile to describe the process in detail because new products come out so rapidly that the particular hardware and software we used is already out of date. If you wish to get set up to create a flattened and compressed Mac and PC compatible movie collection with title screens, you will probably have different, and hopefully more user-friendly software and hardware available.

Digital Capturing and Cropping

We installed a RasterOps MoviePak capture card in a Macintosh Centris 650 computer and used the RasterOps MediaGrabber™ (version 2.5.2, 1993) to capture images either directly from an S-VHS video camera or from a videotape played back through our S-VHS camera. We always set MediaGrabber to collect a half size image (quarter screen). If we knew the motion would be relatively slow, we set MediaGrabber for a slower frame rate than the default 30 frames/second. Once the event of interest was captured, we tried to eliminate extra frames at the beginning and at the end of the captured segment. Finally, we would save the movie on the Centris hard drive.

If the movie needed cropping we would then open it using software entitled ConvertToMovie™ which was distributed with QuickTime 2.0 development CD in 1994 by Apple Computer, Inc. We found it impossible to resize a cropped movie without degrading the image quality significantly, so we just left the cropped movies small.

Adding Title Screens

In order to add a title screen to a movie, we opened the movie using version 2.0.6 of the MoviePlayer™ basic editing software which was distributed with QuickTime 2.0 in 1994 by Apple Computer, Inc. If needed, we used the basic editing feature of MoviePlayer to eliminate a few more frames at the beginning and end of the movie. Next, the first frame of the movie was copied and pasted into version 3.5 of Adobe SuperPaint. Logos, masses, scaling factors and other information of interest were laid on top of the image. The composite image with its title screen was then pasted back as the first frame of the movie in the MoviePlayer software. Unfortunately, the image quality suffered when each first frame was moved into and back out of SuperPaint because it was reduced to an 8-bit color image. If you view the movies on a computer that supports more than 8-bit color, you will notice that the title frames are of consistently of lower quality than the rest of the movies.

Post Compression

Each newly titled movie was then opened again using the ConvertToMovie software. It was then compressed using the Cinepak compression/decompression format, "flattened" and saved as an independent movie. At this point each movie emerged with a smaller file size and played noticeably faster when opened up under MoviePlayer or VideoPoint.

Assignment to VideoPoint

In order to assure that the movie was correctly flattened for use with PC computers also and to associate it with VideoPoint, the movie was opened under a routine we wrote to do this called VideoPoint Flattener. Thus, each movie in the collection can be opened on any computer that can play QuickTime movies, and the assign-

ment to VideoPoint is indicated by the appearance of the VideoPoint icon in the middle of the QuickTime movie icon. Although each assigned movie can be opened, edited and played using MoviePlayer and other playback and editing software, double clicking on an assigned movie will open it along with the VideoPoint software.

7.3. Browsing in the Collection

How the Movies are Cataloged

A data base has been collected for the movies. The data base record for each movie includes a DOS compatible file name and a descriptive movie name. Each movie has been assigned to a topical category such as 1D Motions, Collisions, Human Motions, etc. Finally, a short description has been written for each movie that includes data on the frame rate on which it was digitized. Additional information about each movie is included on its title screen.

Title Screens

Each movie in the collection has been given a title screen that identifies which set of movies it belongs to and includes an object or markers that can be used for scaling purposes. Also, data such as the masses of various objects of interest are included.

Removing a Title Screen

Instructors may want to remove title screens in order to withhold some of the data such as masses, angles and/or scaling markers, so that assignments using the movie can involve finding the missing factors. To remove a movie title screen, the movie must be moved to a read/write disk and opened using an editing routine such as MoviePlayer. The first frame of the movie can then be removed, and the movie can be saved with another filename.

File and Movie Names

The electronic file name for each movie is DOS compatible and is headed by an abbreviation that designates the set to which the movie belongs. The file name header is followed by a three digit serial number for each movie in a set. Finally the three letter extension .MOV has been added to each file name. Typical File Names are PASCO104.MOV, DSON010.MOV, PRU035.MOV and so on.

The Movie Names are only three or four words long and are descriptive of the contents of the movie. For example the DSON001.MOV of a cue ball hitting the rest of the pool balls on the table just after the rack is removed is entitled "Pool Ball Break."

Categories and Descriptions

The movies have been divided into the following categories:

- •1D Motion
- •1D Collision
- •2D Motion
- •Cart Acceleration
- •Electrostatics
- •Human Motion/Sports
- •Inclined Plane Motion
- •Macro Kinetic Theory
- •Oscillation
- •Projectile Motion
- •Rotational Motion
- •Vertical Motion
- •Wave Motion

Each movie in the data base is listed with a two or three sentence description with a number of key words in it. This allows you to find movies of interest without knowing the assigned categories.

The Movie Browser

A new program informally known as the Movie Browser has been created to help you find movies of interest. After opening the Movie Browser, you can search the movie data base by File Name, Movie Name or Category. Or, you can do a key word search on any of the words in the data base including key words in the movie descriptions. Although we found that it was not always obvious how to assign movies to categories, each movie was assigned to only one category. For example, a movie of a ballet dancer doing a grand jeté was put in the Human Motions/Sports category, but it could also have been put in the 2D Motion or Projectile Motion categories. In many cases we have mentioned alternative categories in the movie description. If you want to find all movies that might belong to a category, you should direct a search for it in the Category box and in the movie description box at the same time.

Once a search is initiated, a list of the movie names of the movies identified in the search will appear. The movie on the list you choose will be highlighted and opened. You can then: (1) play to movie, (2) launch it with VideoPoint for analysis, (3) add the information in that movie's data base to a report, (4) view the report with all the movie information sent to it and (5)save, edit or print out the report.

The Movie Browser contains an on-line bubble-type help and can be used easily without further instructions. A typical Movie Browser screen is shown in Figure 7-1.

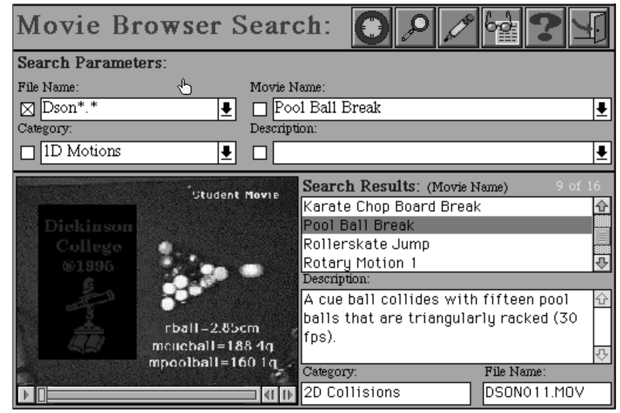

Figure 7-1: The search screen for the Movie Browser software.

7.4. The Collection

The PASCO Laboratory-Based Movies

Credits

A set of approximately 160 movies were filmed at PASCO scientific under the direction of Priscilla Laws and Mark Luetzelschwab. Most of these movies feature PASCO apparatus such as the low-friction dynamics carts and ramps, ballistic pendula, and projectile launchers. The movies were filmed by Allen Steinhofel and John Rice. Most of the apparatus was set up by Jon and Ann Hanks who teach physics at American River College. Robert Morrison from PASCO also helped with the setups. Special equipment such as the traveling pendulum was prepared for the filming by prototype machinists Tom Frieholtz and Sean Malone. Several of these individuals appear in the movies along with other PASCO employees. These extras include: Sean Malone (in the Shoot the Target movies), Mike Cowden (in the Projectile movies), Tracy Montz (in the Diatomic Cart movies) and Michelle Eastin (in Shoot the Target Movies). We owe a vote of thanks to Paul Stokstad, PASCO's president, for arranging for the filming and making all of the apparatus available for our use.

Marker Carts for the Study of Galilean Relativity

In a number of the movies involving PASCO's dynamics carts running on tracks, you will notice three levels of tracks. In general, the events of interest, such as accelerations and collisions occur on the top track. The carts on the other two tracks are set in motion at constant velocity and serve as inertial reference frames for analyses involving Galilean relativity. In is easy to use VideoPoint to obtain information about how various events look to a laboratory observer and to observers in the frames of reference of the cart moving from left to right and the one moving from right to left.

Warnings!

The details of how the apparatus pictured in some of the movies is not obvious from the brief descriptions in the movie data base. Consulting a PASCO catalog or contacting PASCO scientific to get instructions for the apparatus in question might be very helpful in some cases. PASCO's email address for inquiries is sales@pasco.com, phone 800/872-8700.

A few of the movies were made with apparatus designed by machinists Tom Frieholtz and Sean Malone, especially for studying center of mass motions. These items include the U-shaped cart shown in PASCO067.MOV and PASCO068.MOV and the traveling pendulum shown in PASCO069.MOV and PASCO070.MOV. These items will not be found in the PASCO Catalog.

Not all of these movies have been analyzed. There is a small amount of friction in all of the cart motion movies, and in some cases we are aware that extra friction is present because the carts were not completely aligned with the ramp. Nevertheless, these represent real events and we decided to include them. Instructors planning assignments based on these movies should always analyze them first to see what wrinkles are present.

The Princeton University Air Table Movies

Credits

Another set of 40 movies were made in the historic introductory physics laboratory at Princeton University. These movies were filmed at Princeton by Mark Luetzelshwab, Priscilla Laws and David Jackson from the Workshop Physics Project Group at Dickinson College. We owe thanks to Professor David Wilkinson of the Princeton University Department of Physics and Astronomy for granting us permission to use apparatus developed for the introductory physics laboratory program. As part of that program students use specially designed air tables along with video capture and analysis to explore two-dimensional collisions and macroscopic analogs to thermal processes.

2D Collisions and Macroscopic Thermodynamics

The movies of elastic and inelastic collisions on an air table are valuable in the study of two-dimensional collisions and dynamic center of mass concepts. Since the Princeton air tables have built in "energizers," the movies of single-puck motions can be used to help students understand the simplified derivations relating pressure, volume, and temperature in a gas to single-particle kinetic energies. The multi-puck movies provide macroscopic analogs that help students understand the concepts of mean free paths and velocity distributions in a gas as well as entropy phenomena.

Caveats!

Not all of these movies have been analyzed. There is a small amount of friction in all of the puck motion, and in some cases we are aware that extra friction is present due to the pucks rubbing against the airtable in poorly aligned collisions. These collisions in which hidden momentum is transferred to the air table represent real events, and we decided to include them. Instructors planning assignments based on these movies should always analyze them first, to see what surprises might be present.

Because we did not have a monitor available, the field of view was quite large during the filming. Thus the movies in the Princeton set have been cropped, so that they are less than the quarter-screen size of most of the other movies in the collection.

The University of Maryland Traveling Wave Movies

Credits

Although this movie set was actually filmed at Dickinson College, the set is a University of Maryland creation because the films were made by graduate students John Lello and Michael Whitman in their Physics Education research group. These movies are being used in tutorials on traveling waves at Maryland.

Generating the Waves

These movies were made using springs obtained from an industrial supplier. Each spring had an unstretched length of about 1.8m and a masses of about 70g. The k factor for these springs is about 3 N/m. When one of these strings is stretched a length of anywhere from 4 to 6 meters and plucked, then a traveling wave having a speed of anywhere from 7 to 11 m/s is generated. John and Michael mounted a video camera on the ceiling of the lab and filmed wave pulses traveling under different tensions with various amplitudes. They captured constructive and destructive interferences of waves traveling in opposite directions and set up wave reflections at fixed and free ends. One observer commented that the movies actually looked like animations! We suggest that instructors who want to use these movies acquire some similar springs and perform the live demonstrations of the same phenomena in the classroom.

Caveats!

Although these movies are terrific for viewing and measuring some aspects of traveling wave motions, there are some problems with the movies. First, the tension data were taken with a very crude spring scale and are unreliable. Thus, in many cases we did not attempt to report these data. In addition, one can readily see from the movies that the small displacement approximation that is typically used to derive the traveling wave equation does not apply to these movies. This means that the relationship between wave speed, tension and mass per unit length may not apply very well to these wave pulses, even if the tensions had been accurately determined. Also, these movies should eventually be redone with a high speed video camera since 30 frames per second is too slow to see details of the 10 m/s wave pulse shapes as they travel along.

Nevertheless, the filming of traveling waves seems like a terrific way to record and learn about some important properties of waves traveling along springs.

The Dickinson College Movies

About the Dickinson Movies

The Dickinson movie set is quite eclectic. Diving, ballet, karate, freefall at an amusement park and colliding pool balls are included. Some of these movies were made during Workshop Physics classes at Dickinson College while others have been created or collected by students and faculty for use in homework assignments and projects. These movies were chosen because of the interesting physics in them and not for their technical beauty. Those marked as student movies on the title screen give an indication of the types of movies students can make on their own.

We are especially proud of two movies made by students during Dickinson College Workshop Physics classes on electricity. The DSON015.MOV movie enables users to verify the inverse square law for electrostatic repulsion between two negatively charged spheres that are metal coated. You should take note of the fact that the inverse square law does not hold when the spheres are close enough together to distort each others' charge distributions. DSON016.MOV depicts electrostatic repulsion forces between a charged disk and a sphere.

The NASA Rocket and LEM Launch Movies

About the NASA Movies

The NASA movie set consists of a series of launches. Five of the six movies depict the first two seconds or so of rocket liftoffs. Several of these are historic and provide prime examples of constantly accelerated motion. Finding rocket accelerations makes good exercises in the study of kinematics.

The mass of each rocket with full fuel is listed on the movie title screen when it is available. These data can be used in homework assignments in which students are asked to draw free body diagrams that include engine thrust forces and gravita-

tional forces, use the VideoPoint software to find rocket accelerations, and then calculate the engine thrust forces.

The sixth NASA movie, NASA003.MOV, depicts the launch of the Lunar Module during one of the last Apollo missions. It is a special challenge to analyze because the video camera left behind on the moon is programmed to zoom back as the lunar module ascends. This is a good movie to use for student projects. It provides students with an opportunity to use the VideoPoint frame-by-frame scaling feature.

The Hersheypark Movies

About the Hersheypark Movies

The movies in this set were filmed by Mark Luetzelschwab at the Hersheypark Amusement Park in Hershey, Pennsylvania. Hersheypark boasts four different roller coasters—the Sooperdooperlooper, the Sidewinder, the Comet and the Trailblazer. Thus, the majority of this movie set depicts roller coaster trains going up hill, down hill, both up and down hill, and doing loops. Two water boat rides, the Coal Cracker and the Tidal Force, reveal constant accelerations as the boats slide down inclines or slow down in water. The Cyclops ride exemplifies a constant rotational velocity while the Flying Falcon ride depicts a complex set of rotational motions which an be analyzed using VideoPont's moving origin feature linked with a user-defined polar coordinate system. The Pirat ride movie enables users to analyze the motion of a giant physical pendulum.

Caveats!

Although there are no reliable scale factors in many of the movies, the use of pixel units is fine for keeping track of energy transformations. It is difficult to calculate the motions of a roller coaster theoretically, because the trains are long relative to the curvature of the tracks. In some cases the front train car is hard to see clearly, and in others it disappears behind a bush for a few frames. The camera axis is not always perpendicular to the plane of motion of the trains. In spite of the challenges the analysis of these real world images present, these roller coaster scenes provide many excellent examples of mechanical energy transformations.

The Dickinson College Movies

Demon Drop Vertical Fall **DSON001.MOV**

Vertical Motion The Sandusky Amusement Park Demon Drop cage holding four people undergoes free fall. The hand held camera wobbles a bit (15 fps).

Demon Drop Slow Down **DSON002.MOV**

Cart Acceleration The Sandusky Amusement Park Demon Drop cage with four people in it slows down on a horizontal track and almost comes to rest. The hand held camera wobbles a bit (15 fps).

Volleyball Serve **DSON003.MOV**

Human Motion/Sports A student hits a volleyball over a net with an overhead serve. Topspin causes the ball to sink more rapidly than -9.8 m/s/s (30 fps).

Volleyball Spike **DSON004.MOV**

Human Motion/Sports Mark Luetzelschwab spikes a volleyball over a net with topspin. After the ball bounces it loses its spin and undergoes projectile motion following a parabolic path (30 fps).

Boomerang Toss **DSON005.MOV**

Projectile Motion A boomerang is tossed and rotates as it moves. The movie is not scaled. The challenges are to find the boomerang center of mass dynamically and then to find a scale factor that provides a downward acceleration of 9.8 m/s/s (30 fps).

Plain Juggling **DSON006.MOV**

Human Motion/Sports Doug Bowman juggles three balls in standard cascade formation. The vertical motion, the projectile motion, and the impulse and momentum change associated with each throw can be studied. Frames are dropped, but time codes are correct (30 fps).

Fancy Juggling **DSON007.MOV**

Human Motion/Sports Doug Bowman juggles three balls with some original variations. The vertical motion, the projectile motion, and the impulse and momentum change associated with each throw can be studied. Frames are dropped, but time codes are correct (30 fps).

Grand Jeté **DSON008.MOV**

Human Motion/Sports Central Pennsylvania Youth Ballet dancer Carrie Imler performs a grand jeté. This movie can be used to determine center of mass and head motion and learn about the floating illusion in ballet. Her center of mass undergoes projectile motion (30 fps).

Tour Jeté **DSON009.MOV**

Human Motion/Sports Professional dancer Benjamin Pierce performs a tour jeté or turning jump (30 fps).

Four Puck Collision **DSON010.MOV**

2D Motion Four pucks shaped respectively like a triangle, circle, semi-circle, and ‘U’ collide elastically on an air table (30 fps).

Pool Ball Break **DSON011.MOV**

2D Motion A cue ball collides with fifteen pool balls that are triangularly racked. There are too few pre-break frames to determine its initial momentum accurately. Momentum conservation can be used to find the initial momentum of the cue ball (30 fps).

Karate Chop Board Break **DSON012.MOV**

Human Motion/Sports A student breaks through eight pine boards with a downward karate chop. The impulse-momentum theorem can be used to estimate forces (30 fps).

Rotary Motion 1 **DSON013.MOV**

Rotational Motion A hanging mass on a string unwinds from a spool attached to a disk that rotates. This is a far view of the vertical motion of the hanging mass (6 fps).

Rotary Motion 2 **DSON014.MOV**

Rotational Motion A hanging mass on a string unwinds from a spool attached to a disk that rotates. This is a close-up view of the hanging mass (6 fps).

Coulomb Forces **DSON015.MOV**

Electrostatics A prod consists of a charged sphere with a conducting surface that is attached to an insulated rod. This prod repels a similarly charged hanging sphere, demonstrating Coulomb’s law of electrostatic forces (10 fps).

Disk/’Point Charge’ Interaction **DSON016.MOV**

Electrostatics A prod consists of a charged, conducting disk that is attached to an insulated rod. This prod repels a charged sphere with a conducting surface that is hanging (10 fps).

Vertical Ball Toss **DSON017.MOV**

Vertical Motion A ball that is tossed vertically undergoes free fall as it rises, turns around and falls as it undergoes 1D motion in the y-direction (30 fps).

Rollerblade Jump **DSON018.MOV**

Human Motion/Sports A student on in-line skates jumps over an obstacle. Every third frame was dropped, but the time codes seem to be correct. No scale is available, so the challenge is to find one that gives a downward center of mass acceleration of - 9.8 m/s/s (30 fps).

3m Forward Dive Pike **DSON019.MOV**

Human Motion/Sports Grant Braught jumps off a 3 m spring board, does a pike, and dives into a pool. He gains initial momentum from bouncing on the board, and then his center of mass undergoes projectile motion. The camera pans at the end (30 fps).

1m Forward Dive Pike **DSON020.MOV**

Human Motion/Sports Jill Braught jumps forward off a 1 m spring board and gains initial momentum by bouncing on the board. She does a forward dive pike and enters the water head first. Her center of mass undergoes projectile motion during the dive as the camera pans (30 fps).

1m Forward Dive, 2 SS tuck — DSON021.MOV

Human Motion/Sports Jill Braught jumps off a 1m spring board, does a forward dive with 2 somersaults tuck and enters the pool feet first. She gains initial momentum from bouncing on the board, and then her center of mass undergoes projectile motion (30 fps).

1m Inward Dive Pike — DSON022.MOV

Human Motion/Sports Jill Braught jumps backward off a 1m spring board and gains initial momentum by rocking the board. She does an inward dive pike and enters the pool head first. Her center of mass undergoes projectile motion as the camera pans (30 fps).

1m Inward Dive, 1-1/2 SS tuck — DSON023.MOV

Human Motion/Sports Jill Braught jumps backward off a 1m spring board. She gains initial momentum as she rocks the board, does an inward dive with 1-1/2 somersaults tuck and enters the water head first. The camera pans to catch her center of mass projectile motion (30 fps).

1m Backward Dive Straight — DSON024.MOV

Human Motion/Sports Jill Braught jumps backward off a 1m spring board and gains initial momentum as she rocks the board. She does a backward dive straight and enters the water head first. Her center of mass undergoes projectile motion as the camera pans (30 fps).

1m Backward Dive, 1-1/2 SS tuck — DSON025.MOV

Human Motion/Sports Jill Braught jumps backward off a 1m spring board, gaining initial momentum as she rocks the board. She does a back dive with 1-1/2 somersaults tuck to enter the water head first. Her center of mass undergoes projectile motion as the camera sweeps (30 fps)

1m Reverse Dive, 1-1/2 SS tuck — DSON026.MOV

Human Motion/Sports Jill Braught jumps off a 1 m spring board, gaining initial momentum as she bounces on the board. She does a reverse dive with 1-1/2 somersaults tuck to enter the pool head first. Her center of mass undergoes projectile motion as the camera pans (30 fps).

The Hersheypark Movies

Cyclops Ferris Wheel Rotation — HRSY001.MOV

Rotational Motion Many cars on the large rapidly moving Cyclops ferris-wheel rotate in a clockwise direction at a tilt angle of 87° with respect to the horizontal (10 fps).

Coal Cracker Water Boat Descent — HRSY002.MOV

Inclined Motion The Coal Cracker boat full of people accelerates down a ramp in inclined motion and then slows down on a level water track in a 1D motion. The camera angle is not optimal for quantitative analysis (5 fps).

Coal Cracker Water Boat Slow Down — HRSY003.MOV

Cart Acceleration The Coal Cracker boat full of people that has just accelerated down an incline undergoes a 1D motion as it slows down on a level water track. No scale available, but the nature of the slow down acceleration can be studied (5 fps).

Tidal Force Water Boat Slow Down — HRSY004.MOV

Inclined Motion A 20 passenger Tidal Force boat that has just accelerated down an incline slows down on a level water track causing a large splash that hides the boat. The nature of the motion of the leading edge of the splash can be studied (5 fps).

Flying Falcon w/ Multiple Rotations — HRSY005.MOV

Rotational Motion The Flying Falcon structure with four arms rotates in a large circle. Each arm forms a substructure with a circular array of seven carts on it. Each of these carts rotates in a smaller circle (6 fps).

Pirat Rocking Boat — HRSY006.MOV

Oscillations Pirat, a fake pirate ship, acts as a large physical pendulum as it oscillates on rollers. Its amplitude increases as a kicking device adds energy to the oscillating system (30 fps).

Looper Roller Coaster 1 — HRSY007.MOV

Inclined Motion The SooperdooperLooper roller coaster travels down an inclined track. The camera angle is not optimal for quantitative analysis (5 fps).

Tidal Force Water Boat Acceleration — HRSY008.MOV

Inclined Motion A 20 passenger Tidal Force boat drops about 100 feet vertically on an inclined track (5 fps).

Looper Roller Coaster 2 — HRSY009.MOV

Inclined Motion The SooperdooperLooper roller coaster travels down an inclined track and does a loop-the-loop (5 fps).

Looper Roller Coaster 3 — HRSY010.MOV

Inclined Motion The SooperdooperLooper roller coaster travels down an inclined track and does a loop-the-loop (5 fps).

Sidewinder Roller Coaster 1 — HRSY011.MOV

Inclined Motion The Sidewinder roller coaster travels down an inclined track and does a loop-the-loop (5 fps).

Sidewinder Roller Coaster 2 — **HRSY012.MOV**

Inclined Motion The Sidewinder roller coaster travels down an inclined track and does a loop-the-loop (5 fps).

Sidewinder Roller Coaster 3 — **HRSY013.MOV**

Inclined Motion The Sidewinder roller coaster travels downhill and through two loops. It is then towed up a far hill and released. It falls back down the far hill and travels backwards through the same two loops (30 fps).

Comet Roller Coaster 1 — **HRSY014.MOV**

Inclined Motion The Comet roller coaster travels down one side of a concave track and up the other side (10 fps).

Comet Roller Coaster 2 — **HRSY015.MOV**

Inclined Motion The Comet roller coaster travels up an inclined track (10 fps).

Comet Roller Coaster 3 — **HRSY016.MOV**

Inclined Motion The Comet roller coaster travels down an inclined track (5 fps).

Comet Roller Coaster 4 — **HRSY017.MOV**

Inclined Motion The Comet roller coaster travels up an inclined track (5 fps).

Comet Roller Coaster 5 — **HRSY018.MOV**

Inclined Motion The Comet roller coaster travels down one side of a concave track and up the other side. A second roller coaster in the background travels along a roughly level track (5 fps).

Comet Roller Coaster 6 — **HRSY019.MOV**

Inclined Motion The Comet roller coaster travels down one side of a concave track and up the other side (5 fps).

The NASA Rocket and LEM Launch Movies

V-2 Rocket Launch — **NASA001.MOV**

Vertical Motion A V-2 rocket is launched vertically upward as the camera pans (6 fps).

Saturn V Rocket Launch — **NASA002.MOV**

Vertical Motion A Saturn V Rocket is launched vertically upward in an early Apollo mission as the camera pans (5 fps).

Apollo Lunar Module Launch — **NASA003.MOV**

Vertical Motion An Apollo Lunar Module is launched from the surface of the moon as the remote camera zooms back and pans upward (10 fps).

Space Shuttle Launch — **NASA004.MOV**

Vertical Motion The Space Shuttle Columbia is launched vertically upward (6 fps).

Mercury-Redstone Launch — **NASA005.MOV**

Vertical Motion A Mercury-Redstone rocket launches Alan Shepard's 15 minute and 22 second suborbital space flight on May 5, 1961. Shepard becomes the first American in space (5 fps).

Jupiter C Launch — **NASA006.MOV**

Vertical Motion A Jupiter C rocket is used to launch the Explorer I satellite (5 fps).

The PASCO Laboratory-Based Movies

Magnetic Bumper Collision 1 — **PASC0001.MOV**

1D Collision A cart collides with a magnetic bumper at a low velocity. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Magnetic Bumper Collision 2 — **PASC0002.MOV**

1D Collision A cart collides with a magnetic bumper at a high velocity. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Fan Cart Accelerating from Rest 1 — **PASC0003.MOV**

Cart Acceleration A fan cart with low thrust starts from rest and accelerates to the left. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Fan Cart Accelerating from Rest 2 — **PASC0004.MOV**

Cart Acceleration A fan cart with high thrust starts from rest and accelerates to the right. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Fan Cart Accelerating Back and Forth 1 — **PASC0005.MOV**

Cart Acceleration Initially a fan cart starts moving to the right opposite a low fan thrust. It then turns around and moves back. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Fan Cart Accelerating Back and Forth 2 — **PASC0006.MOV**

Cart Acceleration Initially a fan cart starts moving to the right opposite a high fan thrust. It then turns around and moves back. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Fan Cart Accelerating Back and Forth 3 — PASCO007.MOV

Cart Acceleration Initially a fan cart starts moving to the left opposite a high fan thrust. It then turns around and moves back. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Fan Cart Accelerating Down Incline 1 — PASCO008.MOV

Inclined Motion A fan cart with its fan off starts from rest and moves down an incline. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Fan Cart Accelerating Down Incline 2 — PASCO009.MOV

Inclined Motion A fan cart is set up with a high thrust that opposes the gravitational force component. It starts from rest and speeds up as it moves down an incline (5 fps).

Fan Cart Accelerating Up Incline — PASCO010.MOV

Inclined Motion A fan cart is set at a high thrust that opposes the gravitational force component. It starts up an incline with a positive initial velocity and slows down. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Magnetic Bumper Collision 3 — PASCO011.MOV

Inclined Motion A cart rolls a short distance down a slight incline and collides with a magnetic bumper. It bounces and undergoes about a dozen oscillations before coming to rest (5 fps).

Magnetic Bumper Collision 4 — PASCO012.MOV

Inclined Motion A cart rolls a long distance down a slight incline and collides with a magnetic bumper. It bounces and undergoes about a dozen oscillations before coming to rest (5 fps).

Elastic Cart Collision on an Incline 1 — PASCO013.MOV

Inclined Motion Two carts with magnets on their ends have equal mass and speed. They undergo an elastic head-on collision while accelerating on a slight incline (5 fps).

Elastic Cart Collision on an Incline 2 — PASCO014.MOV

Inclined Motion Two carts with the same mass have magnets installed in their ends. The fast cart undergoes an elastic collision with a slower cart moving in the same direction. Both carts are accelerating down a slight incline (6 fps).

Inelastic Cart Collision on Incline 1 — PASCO015.MOV

Inclined Motion Two carts of equal mass travel on a small incline and undergo an inelastic head-on collision (6 fps).

Inelastic Cart Collision on Incline 2 — PASCO016.MOV

Inclined Motion A fast cart collides inelastically with a slow cart of equal mass moving in the same direction down a small incline (6 fps).

Elastic Cart Collision 1 — PASCO017.MOV

1D Collision Two carts with the same mass have magnets installed in their ends. A slow cart undergoes an elastic collision with a stationary cart of equal mass. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Elastic Cart Collision 2 — PASCO018.MOV

1D Collision Two carts with the same mass have magnets installed in their ends. The carts are moving slowly when they undergo an elastic collision. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Elastic Cart Collision 3 — PASCO019.MOV

1D Collision Two slow carts with unequal masses undergo an elastic collision. These carts have magnets installed in their ends. Two lower carts provide inertial frames for the study of Galilean relativity (10 fps).

Elastic Cart Collision 4 — PASCO020.MOV

1D Collision A cart with lesser mass undergoes an elastic collision with a stationary cart of greater mass. These carts have magnets installed in their ends. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Elastic Cart Collision 5 — PASCO021.MOV

1D Collision A cart with greater mass undergoes an elastic collision with a stationary cart of lesser mass. These carts have magnets installed in their ends. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Elastic Cart Collision 6 — PASCO022.MOV

1D Collision A fast cart with greater mass undergoes an elastic collision with a slower less massive cart moving in the same direction. These carts have magnets in their ends. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Elastic Cart Collision 7 — PASCO023.MOV

1D Collision Two carts have magnets installed in their ends. A fast cart collides elastically with a slow cart with larger mass moving in the same direction. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Cart Collision 1 — PASCO024.MOV

1D Collision A cart collides inelastically with a stationary cart of equal mass. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Cart Collision 2 **PASCO025.MOV**

1D Collision Two carts with almost equal speed and mass undergo a head-on inelastic collision. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Inelastic Cart Collision 3 **PASCO026.MOV**

1D Collision A fast, massive cart collides head-on, inelastically with a slow, less massive cart. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Inelastic Cart Collision 4 **PASCO027.MOV**

1D Collision A cart with small mass collides inelastically with a stationary cart with large mass. Two lower carts provide inertial frames for the study of Galilean relativity (5 fps).

Inelastic Cart Collision 5 **PASCO028.MOV**

1D Collision A cart with large mass collides inelastically with a stationary cart with small mass at rest. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Cart Collision 6 **PASCO029.MOV**

1D Collision A fast cart with large mass collides inelastically with a slow cart with small mass moving in the same direction. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Cart Collision 7 **PASCO030.MOV**

1D Collision A fast cart with small mass collides inelastically with a slow cart with large mass moving in the same direction. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Exploding Carts 1 **PASCO031.MOV**

1D Collision Two carts of equal mass explode in opposite directions. The explosion energy is initially stored in compressed springs (10 fps).

Exploding Carts 2 **PASCO032.MOV**

1D Collision Two carts of unequal mass explode in opposite directions. The explosion energy is initially stored in compressed springs (15 fps).

Exploding Carts 3 **PASCO033.MOV**

1D Collision Two carts of unequal mass explode in opposite directions. The explosion energy is initially stored in compressed springs. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Exploding Carts 4 **PASCO034.MOV**

1D Collision Two carts of equal mass explode in opposite directions. The explosion energy is initially stored in compressed springs. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Fan Cart Acceleration 1 **PASCO035.MOV**

Cart Acceleration A fan cart set on a low thrust accelerates toward the right on a level track. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Fan Cart Acceleration 2 **PASCO036.MOV**

Cart Acceleration A fan cart set on a low thrust is pushing one additional cart. The two carts accelerate along a level track. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Fan Cart Acceleration 3 **PASCO037.MOV**

Cart Acceleration A fan cart set on a low thrust is pushing two additional carts. The three carts accelerate along a level track. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Fan Cart Acceleration 4 **PASCO038.MOV**

Cart Acceleration A fan cart set on a low thrust is pushing three additional carts. The four carts move along a level track. Friction is significant. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Elastic Fan Cart Collision 1 **PASCO039.MOV**

1D Collision A fan cart system on low thrust collides elastically with a less massive stationary cart. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Elastic Fan Cart Collision 2 **PASCO040.MOV**

1D Collision A fan cart system on low thrust undergoes a series of elastic collisions with a two-cart stack that is initially at rest. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Elastic Fan Cart Collision 3 **PASCO041.MOV**

1D Collision A fan cart system on low thrust undergoes a series of elastic collisions with a three-cart stack that is initially at rest. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Fan Cart Collision 1 **PASCO042.MOV**

1D Collision A fan cart system on low thrust collides inelastically with a less massive stationary cart. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Fan Cart Collision 2 — PASCO043.MOV

1D Collision A fan cart system on low thrust undergoes an inelastic collision with a two-cart stack that is initially at rest. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Inelastic Fan Cart Collision 3 — PASCO044.MOV

1D Collision A fan cart system on low thrust undergoes an inelastic collision with a three-cart stack that is initially at rest. There is considerable friction after the collision. Two lower carts provide inertial frames for the study of Galilean relativity (6 fps).

Ballistic Cart Ball Launch-Catch 1 — PASCO045.MOV

Projectile Motion A slow ballistic cart launches a ball and catches it. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Ballistic Cart Ball Launch-Catch 2 — PASCO046.MOV

Projectile Motion A fast ballistic cart launches a ball and catches it. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Ballistic Cart Ball Drop-Catch — PASCO047.MOV

Projectile Motion A slow ballistic cart equipped with a drop rod drops a ball and catches it. Two lower carts provide inertial frames for the study of Galilean relativity. Frames were dropped in digitization, but time codes are correct (15 fps).

Ballistic Launch-Catch on Incline 1 — PASCO048.MOV

Projectile Motion A slow ballistic cart is undergoing a downward inclined motion. It launches and catches a ball. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Ballistic Launch-Catch on Incline 2 — PASCO049.MOV

Projectile Motion A slow ballistic cart is undergoing an upward inclined motion. It launches and catches a ball. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Ballistic Launch-Catch on Incline 3 — PASCO050.MOV

Projectile Motion A fast ballistic cart is undergoing an upward inclined motion. It launches and catches a ball. Two lower carts provide inertial frames for the study of Galilean relativity (15 fps).

Slow Cart Rolling Down Incline — PASCO051.MOV

Inclined Motion A cart moves with a low velocity on a level track and travels down an incline to a lower level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Fast Cart Rolling Down Incline — PASCO052.MOV

Inclined Motion A cart moves with a high velocity on a level track and travels down an incline to a lower level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Slow Cart Rolling Up Incline — PASCO053.MOV

Inclined Motion A cart moves with a low velocity on a level track and travels up an incline to a higher level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Fast Cart Rolling Up Incline — PASCO054.MOV

Inclined Motion A cart moves with a high velocity on a level track and travels up an incline to a higher level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Fan Cart Rolling Up Incline — PASCO055.MOV

Inclined Motion A fan cart, starting from rest on a level track, experiences a low thrust force and travels up an incline to a track at a higher level. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Slow Fan Cart Rolling Down Incline — PASCO056.MOV

Inclined Motion A fan cart moves to the left on a level track opposite to the direction of the low thrust it experiences. It then travels down an incline to a lower level track. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Fast Fan Cart Rolling Down Incline — PASCO057.MOV

Inclined Motion A fan cart moves to the left on a level track opposite to the direction of the high thrust it experiences. It then travels down an incline to a lower level track. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Rolling Up Incline w/ Fan Off — PASCO058.MOV

Inclined Motion A fan cart with its fan off moves to the right on a level track. It then travels up an incline to a higher level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Moving Down Incline w/ Fan Off 1 — PASCO059.MOV

Inclined Motion A fan cart with its fan off moves to the left on a level track. It then travels down an incline to a lower level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Moving Down Incline w/ Fan Off 2 — PASCO060.MOV

Inclined Motion A fan cart with its fan off moves to the left on a level track. It then travels down an incline to a lower level. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Moving Up Two Inclines — PASCO061.MOV

Inclined Motion A cart moves slowly down an incline, over a level section, and down another incline. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Moving Down Two Inclines — PASCO062.MOV

Inclined Motion A cart moves slowly up an incline, over a level section, and up another incline. This motion tests mechanical energy conservation. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Fan Cart Moving Up Two Inclines — PASCO063.MOV

Inclined Motion A fan cart moves slowly up an incline, over a level section and up another incline in the direction of the high thrust it experiences. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Fan Cart Moving Down Two Inclines — PASCO064.MOV

Inclined Motion A fan cart moves slowly down an incline, along a level section and down another incline. It moves opposite to the direction of the low thrust it experiences. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Released from Mobile Incline 1 — PASCO065.MOV

Inclined Motion A cart accelerates down an incline that has wheels. This incline can roll on a level track. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Released from Mobile Incline 2 — PASCO066.MOV

Inclined Motion A cart accelerates down an incline that has wheels. This incline can roll on a level track. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Released from Mobile Half Pipe 1 — PASCO067.MOV

Oscillations A cart oscillates inside a concave ramp that has wheels. This concave ramp can roll on a level track. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Cart Released from Mobile Half Pipe 2 — PASCO068.MOV

Oscillations A cart oscillates inside a concave ramp that has wheels. This concave ramp can roll on a level track. Two lower carts provide inertial frames for the study of Galilean relativity (30 fps).

Mobile Triangle Frame Pendulum 1 — PASCO069.MOV

Oscillations A pendulum mounted on a triangular frame oscillates. The triangular frame is mounted on wheels and can roll along a level track (30 fps).

Mobile Triangle Frame Pendulum 2 — PASCO070.MOV

Oscillations A pendulum mounted on a triangular frame oscillates. The triangular frame is mounted on wheels and can roll along a level track (30 fps).

Diatomic' Cart System Collision 1 — PASCO071.MOV

Macro Kinetic Theory A slow cart collides elastically with two stationary carts that are connected by a metal-leaf spring. The connected carts undergo horizontal oscillations and store vibrational energy like a diatomic molecule (15 fps).

Diatomic' Cart System Collision 2 — PASCO072.MOV

Macro Kinetic Theory A slow massive cart collides elastically with two stationary carts that are connected by a metal-leaf spring. The connected carts undergo oscillations and store vibrational energy like a diatomic molecule (15 fps).

Diatomic' Cart System Collision 3 — PASCO073.MOV

Macro Kinetic Theory Two carts connected by a metal-leaf spring undergo horizontal oscillations. This cart system stores vibrational energy like a diatomic molecule. There are a couple of missing frames, but the time codes are correct (30 fps).

Diatomic' Cart System Collision 4 — PASCO074.MOV

Macro Kinetic Theory A slow cart collides elastically with two oscillating carts that are connected by a metal-leaf spring. The connected carts undergo oscillations and store vibrational energy like a diatomic molecule (15 fps).

Diatomic' Cart System Collision 5 — PASCO075.MOV

Macro Kinetic Theory A slow cart collides elastically with two carts that are connected by a metal-leaf spring. The connected carts undergo oscillations and store vibrational energy like a diatomic molecule (15 fps).

Diatomic' Cart System Collision 6 — PASCO076.MOV

Macro Kinetic Theory Two carts connected by a metal-leaf spring slowly collide with a stationary cart. The connected carts undergo oscillations and store vibrational energy like a diatomic molecule (15 fps).

Diatomic' Cart System Collision 7 — PASCO077.MOV

Macro Kinetic Theory Two carts connected by a metal-leaf spring slowly collide with a stationary cart. The connected carts undergo oscillations and store vibrational energy like a diatomic molecule (15 fps).

Elastic Cart Collision 8 — PASCO078.MOV

1D Motion A slow cart with small mass collides elastically with a stationary cart with more mass (6 fps).

Elastic Cart Collision 9 **PASCO079.MOV**

1D Motion A slow cart with small mass collides elastically with a more massive slow cart (5 fps).

Elastic Cart Collision 10 **PASCO080.MOV**

1D Motion A slow cart with small mass collides elastically with a more massive stationary cart (5 fps).

Elastic Cart Collision 11 **PASCO081.MOV**

1D Motion A slow cart with small mass undergoes a head-on collision with a more massive slowly moving cart.

Inelastic Cart Collision 8 **PASCO082.MOV**

1D Motion A slow cart with small mass collides inelastically with a stationary cart with more mass. Some momentum is transferred to the track during the collision (5 fps).

Inelastic Cart Collision 9 **PASCO083.MOV**

1D Motion A slow cart with small mass collides inelastically with a slow cart with more mass. This collision shows relatively little momentum loss to the track (6 fps).

Inelastic Cart Collision 10 **PASCO084.MOV**

1D Motion A slow cart with small mass collides inelastically with a slow cart with more mass. The collision shows relatively little momentum loss to the track (6 fps).

Inelastic Cart Collision 11 **PASCO085.MOV**

1D Motion A slow cart with small mass collides inelastically with a stationary cart with more mass. This collision shows momentum loss to the track (5 fps).

Inelastic Cart Collision 12 **PASCO086.MOV**

1D Motion A slow cart with small mass collides inelastically with a slow cart with more mass. This collision shows relatively little momentum loss to the track (15 fps).

Inelastic Cart Collision 13 **PASCO087.MOV**

1D Motion A slow cart with small mass collides inelastically with a fast cart with more mass. This collision shows relatively little momentum loss to the track (5 fps).

Modified Atwood's 1 (0°) **PASCO088.MOV**

Cart Acceleration A cart on a level track is accelerated by a small, falling mass in a modified Atwood's machine (6 fps).

Modified Atwood's 2 (0°) **PASCO089.MOV**

Cart Acceleration A cart on a level track is accelerated by a large, falling mass in a modified Atwood's machine (6 fps).

Modified Atwood's 3 (0°) **PASCO090.MOV**

Cart Acceleration A double cart on a level track is accelerated by a small, falling mass in a modified Atwood's machine (5 fps).

Modified Atwood's 4 (0°) **PASCO091.MOV**

Cart Acceleration A double cart on a level track is accelerated by a large, falling mass in a modified Atwood's machine (6 fps).

Modified Atwood's 5 (0°) **PASCO092.MOV**

Cart Acceleration A massive double cart system on a level track is accelerated by a small, falling mass in a modified Atwood's machine (5 fps).

Modified Atwood's 6 (0°) **PASCO093.MOV**

Cart Acceleration A massive double cart on a level track is accelerated by a large falling mass in a modified Atwood's machine (6 fps).

Inclined Modified Atwood's 1 **PASCO094.MOV**

Inclined Motion A cart is accelerated up a 10° incline by a falling mass in a modified Atwood's machine (5 fps).

Inclined Modified Atwood's 2 **PASCO095.MOV**

Inclined Motion A cart is accelerated up a 10° incline by a falling mass in a modified Atwood's machine (6 fps).

Inclined Modified Atwood's 3 **PASCO096.MOV**

Inclined Motion A double cart is accelerated up a 10° incline by a falling mass in a modified Atwood's machine (5 fps).

Inclined Modified Atwood's 4 **PASCO097.MOV**

Inclined Motion A double cart is accelerated up a 10° incline by a falling mass in a modified Atwood's machine (5 fps).

Inclined Modified Atwood's 5 **PASCO098.MOV**

Inclined Motion A cart is accelerated up a 20° incline by a falling mass in a modified Atwood's machine (5 fps).

Inclined Modified Atwood's 6 **PASCO099.MOV**

Inclined Motion A cart is accelerated up a 20° incline by a falling mass in a modified Atwood's machine (5 fps).

Cart-Series Spring Oscillations **PASCO100.MOV**

Oscillations A cart on an incline of about 10° is attached to two identical springs in series and undergoes an inclined motion consisting of a series of oscillations (5 fps).

Inclined Cart-Parallel Spring Motion **PASCO101.MOV**

Oscillations A cart on an incline of about 10° is attached to two identical springs in parallel and undergoes an inclined motion consisting of a series of oscillations (5 fps).

Inclined Cart-Spring Oscillations **PASCO102.MOV**

Oscillations A cart on an incline of about 10° is attached to the same type of spring used in PASCO100 and PASCO101. It undergoes an inclined motion consisting of a series of oscillations (5 fps).

Level Cart-Series Spring Oscillations **PASCO103.MOV**

Oscillations A cart on a level track is attached to two identical springs in series and undergoes a series of oscillations (5 fps).

Projectile Launch No. 1 at ≈ 30° **PASCO104.MOV**

Projectile Motion A hard plastic ball is shot from a projectile launcher at about 30° above horizontal. This movie is used as the PRJCTILE example in Chapter 2 of the User's Guide (30 fps).

Projectile Launch No. 2 at ≈ 30° **PASCO105.MOV**

Projectile Motion A Styrofoam® ball is shot from a projectile launcher at about 30° above horizontal (30 fps).

Projectile Launch No. 1 at ≈ 45° **PASCO106.MOV**

Projectile Motion A hard plastic ball is shot from a projectile launcher at about 45° above horizontal at a high setting (30 fps).

Projectile Launch No. 2 at ≈ 45° **PASCO107.MOV**

Projectile Motion A Styrofoam® ball is shot from a projectile launcher at about 45° above horizontal (30 fps).

Projectile Launch No. 1 at ≈ 60° **PASCO108.MOV**

Projectile Motion A hard plastic ball is shot from a projectile launcher at about 60° above horizontal (30 fps).

Projectile Launch No. 2 at ≈ 60° **PASCO109.MOV**

Projectile Motion A Styrofoam® ball is shot from a projectile launcher at about 60° above horizontal (30 fps).

Shoot the Target at ≈ 42° **PASCO110.MOV**

Projectile Motion A dense plastic ball is shot from a projectile launcher at about 42° and hits a falling target (30 fps).

Shoot the Target at ≈ -20° **PASCO111.MOV**

Projectile Motion A dense plastic ball shot from a projectile launcher at -20° hits a falling target. The ball is so small that it is hard to see. Anticipating the ball's location in each frame and using more than 8-bit color make it possible to spot (30 fps).

Inelastic Ballistic Pendulum **PASCO112.MOV**

Projectile Motion A projectile launcher at its high setting shoots a steel ball at a hanging ballistic pendulum in an inelastic collision. PASCO113.MOV shows the motion of the projectile launched at a high setting (15 fps).

Ballistic Launch Calibration **PASCO113.MOV**

Projectile Motion A steel ball is shot horizontally from a projectile launcher at its high setting. Data from PASCO112.MOV can be used to find the initial velocity of the ball (30 fps).

Inelastic Ballistic Cart **PASCO114.MOV**

Projectile Motion A projectile launcher at its high setting shoots a steel ball at a ballistic cart on a level track in an inelastic collision. PASCO113.MOV shows motion of projectile launched at high setting (6 fps).

Elastic Ballistic Cart **PASCO115.MOV**

Projectile Motion A projectile launcher at its high setting shoots a steel ball at a ballistic cart on a level track in an elastic collision. PASCO113.MOV shows motion of a projectile launched at high setting (6 fps).

Elastic Ballistic Pendulum **PASCO116.MOV**

Projectile Motion A steel ball shot horizontally from a projectile launcher at its high setting hits a hanging ballistic pendulum in an elastic collision. PASCO113.MOV shows motion of projectile launched at high setting (15 fps).

Coffee Filter Drop 1 (13m) **PASCO117.MOV**

Vertical Motion A nested group of 13 coffee filters fall from rest (30 fps).

Coffee Filter Drop 2 (9m) **PASCO118.MOV**

Vertical Motion A nested group of 9 coffee filters fall from rest (30 fps).

Coffee Filter Drop 3 (6m) **PASCO119.MOV**

Vertical Motion A nested group of 6 coffee filters fall from rest (30 fps).

Coffee Filter Drop 4 (4m) **PASCO120.MOV**

Vertical Motion A nested group of 4 coffee filters fall from rest (30 fps).

Coffee Filter Drop 5 (2m) — PASCO121.MOV

Vertical Motion A nested group of 2 coffee filters fall from rest (30 fps).

Coffee Filter Drop 6 (1m) — PASCO122.MOV

Vertical Motion A single coffee filter falls from rest (30 fps).

Coffee Filter Drop w/ Steel Ball — PASCO123.MOV

Vertical Motion A steel ball and a coffee filter crumpled around a steel ball fall from rest simultaneously (30 fps).

Medium Setting, Low Mass Launch 1 — PASCO124.MOV

2D Motion A projectile launcher with a medium setting shoots a yellow ball along a floor. Speed of launch can be used in analyzing PASCO125.MOV and PASCO126.MOV (30 fps).

2D Collision w/ Equal Masses 1 — PASCO125.MOV

2D Motion A projectile launcher with a medium setting shoots a yellow ball horizontally along a floor. It collides head on with a pink ball of similar mass at point-blank range (30 fps).

2D Collision w/ Equal Masses 2 — PASCO126.MOV

2D Motion A projectile launcher with a medium setting shoots a low mass yellow ball horizontally along a floor. It collides at about 90° with another ball of similar mass at point-blank range (30 fps).

2D Collision w/ Unequal Masses 1 — PASCO127.MOV

2D Motion A projectile launcher with an unknown setting shoots a massive steel ball. It collides head on with a low mass plastic ball at point-blank range. Use PASCO130.MOV or PASCO131.MOV for calibration (30 fps).

2D Collision w/ Equal Masses 3 — PASCO128.MOV

2D Motion A projectile launcher with an unknown setting shoots a massive steel ball. It collides at a slight angle with a low mass plastic ball head-on at point-blank range. Use PASCO130.MOV or PASCO131.MOV for calibration (30 fps).

2D Collision w/ Equal Masses 4 — PASCO129.MOV

2D Motion A projectile launcher with an unknown setting shoots a massive steel ball. It collides at point-blank range at about a 90° angle with another steel ball of similar mass. Use PASCO130.MOV or PASCO131.MOV for calibration (30 fps).

Medium Setting, High Mass Launch — PASCO130.MOV

2D Motion A projectile launcher shoots a ball at its medium setting along a floor. Use this motion for calibration of the speed of a steel ball launched at a medium setting in analyzing PASCO127.MOV-PASCO129.MOV (30 fps).

High Setting, High Mass Launch — PASCO131.MOV

2D Motion A projectile launcher shoots a ball at its medium setting along a floor. Use this motion for calibration of the speed of a steel ball launched at a high setting in analyzing PASCO127.MOV-PASCO129.MOV (30 fps).

Coriolis Rotational Launch 1 — PASCO132.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory rotating at a low speed. The x-component of velocity is large. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 2 — PASCO133.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory rotating at a medium speed. The x-component of velocity is large. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 3 — PASCO134.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory rotating at a high speed. The x-component of velocity is large. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 4 — PASCO135.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory that is not rotating. The x-component of velocity is large. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 5 — PASCO136.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory rotating at a high speed. The x-component of velocity is moderate. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 6 — PASCO137.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory that is not rotating. The x-component of velocity is moderate. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 7 — PASCO138.MOV

Rotational Motion A projectile is launched from a Coriolis Effect Accessory rotating at a high speed. The x-component of velocity is small. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 8 — **PASCO139.MOV**

Rotational Motion A projectile is launched from a Coriolis Effect Accessory that is not rotating. The x-component of velocity is small. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Coriolis Rotational Launch 9 — **PASCO140.MOV**

Rotational Motion A projectile is launched from a rotating Coriolis Effect Accessory and an attempt is made to get the launcher to intercept the projectile. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (15 fps).

Coriolis Rotational Launch 10 — **PASCO141.MOV**

Rotational Motion A projectile is launched from a Coriolis Effect Accessory rotating at a high speed. The x-component of velocity is zero. The projectile is hard to see, and it helps to move backward through the frames anticipating its location (30 fps).

Lenz's Law 1 — **PASCO142.MOV**

Vertical Motion A magnetic rod and a non-magnetic rod fall freely near each other. There is no metal nearby to influence the rates of fall (30 fps).

Lenz's Law 2 — **PASCO143.MOV**

Vertical Motion A non-magnetic rod falls through a metal tube (30 fps).

Lenz's Law 3 — **PASCO144.MOV**

Vertical Motion A magnetic rod falls through a metal tube (5 fps).

Variable g Pendulum at 75° to Vertical — **PASCO145.MOV**

Oscillations A rigid pendulum oscillates in a plane that makes a 75° angle with the vertical changing the effective 'g' (6 fps).

Variable g Pendulum at 45° to Vertical — **PASCO146.MOV**

Oscillations A rigid pendulum oscillates in a plane that makes a 45° angle with the vertical changing the effective 'g' (15 fps).

Variable g Pendulum at 30° to Vertical — **PASCO147.MOV**

Oscillations A rigid pendulum oscillates in a plane that makes a 30° angle with the vertical changing the effective 'g' (30 fps).

Variable g Pendulum at 15° to Vertical — **PASCO148.MOV**

Oscillations A rigid pendulum oscillates in a plane that makes a 15° angle with the vertical changing the effective 'g' (30 fps).

Variable g Pendulum at 0° to Vertical — **PASCO149.MOV**

Oscillations A rigid pendulum oscillates in a plane that makes a 0° angle with respect to the vertical. There is no changing the effective 'g' (30 fps).

Standing Wave in Second Harmonic — **PASCO150.MOV**

Wave Motion A metal wire oscillates at 45 Hz in its second harmonic. Nodes are visible, but the wire motion is too rapid to 'stop' (30 fps).

Standing Wave in First Harmonic — **PASCO151.MOV**

Wave Motion A metal wire oscillates at 30 Hz in its first harmonic. Nodes are visible, but the wire motion is too rapid to 'stop' (30 fps).

Standing Wave in Fundamental Mode — **PASCO152.MOV**

Wave Motion A metal wire oscillates at 15 Hz in its fundamental mode (30 fps).

Simple Pendulum w/ Length ≈ 100 cm — **PASCO153.MOV**

Oscillations A simple pendulum with a length of about 100cm oscillates (15 fps).

Simple Pendulum w/ Length ≈ 71 cm — **PASCO154.MOV**

Oscillations A simple pendulum with a length of about 71cm oscillates (30 fps).

Simple Pendulum w/ Length ≈ 50 cm — **PASCO155.MOV**

Oscillations A simple pendulum with a length of about 50cm oscillates (30 fps).

Simple Pendulum w/ Length ≈ 31 cm — **PASCO156.MOV**

Oscillations A simple pendulum with a length of about 31cm oscillates (30 fps).

Simple Pendulum w/ Length ≈ 20 cm — **PASCO157.MOV**

Oscillations A simple pendulum with a length of about 20cm oscillates (30 fps).

Mass Oscillating on a Fixed Spring — **PASCO158.MOV**

Oscillations A mass on a spring oscillates vertically while it is hanging from a rod attached to a stationary cart (30 fps).

Mass Oscillating on a Moving Spring — **PASCO159.MOV**

Oscillations A mass on a spring oscillates vertically while it is hanging from a rod. The rod is attached to a cart that is moving horizontally with a low velocity (30 fps).

The Princeton University Air Table Movies

Puck Collisions w/ Air Table Walls **PRU001.MOV**

Macro Kinetic Theory A single puck bounces off the walls of an air table emulating molecular motion in a box as it undergoes 2D motion. This system is non-adiabatic since the puck loses energy in each bounce (6 fps).

2 Puck Elastic Collision 1 **PRU002.MOV**

2D Motion Two moving pucks collide elastically on an air table (15 fps).

2 Puck Elastic Collision 2 **PRU003.MOV**

2D Motion Two black pucks collide elastically on an air table. They are a bit hard to see against the black air table (15 fps).

2 Puck Inelastic Collision 1 **PRU004.MOV**

2D Motion Two moving pucks collide inelastically on an air table. They rotate rapidly after collision (30 fps).

2 Puck Inelastic Collision 2 **PRU005.MOV**

2D Motion Two moving pucks collide inelastically on an air table. They rotate slowly after collision (6 fps).

2 Puck Inelastic Collision 3 **PRU006.MOV**

2D Motion Two pucks are moving on an air table with a fairly high linear momentum. They undergo an inelastic collision and then rotate slowly demonstrating angular momentum conservation (10 fps).

2 Puck Elastic Collision 3 **PRU007.MOV**

2D Motion Two moving pucks collide elastically on an air table (15 fps).

2 Puck Elastic Collision 4 **PRU008.MOV**

2D Motion Two moving black pucks collide elastically on an air table. They are hard to see against the black surface of the air table (10 fps).

2 Puck Elastic Collision 5 **PRU009.MOV**

2D Motion A moving puck collides elastically with a stationary puck on an air table (6 fps).

2 Puck Elastic Collision 6 **PRU010.MOV**

2D Motion A moving puck collides elastically with a stationary puck on an air table (15 fps).

2 Puck Inelastic Collision 4 **PRU011.MOV**

2D Motion A moving puck collides inelastically with a stationary puck on an air table (15 fps).

Vibrational Molecule Collision 1 **PRU012.MOV**

Macro Kinetic Theory A moving puck undergoes a 2D collision on an air table with a stationary 'diatomic molecule' puck system causing oscillations in the diatomic system (30 fps).

Vibrational Molecule Collision 2 **PRU013.MOV**

Macro Kinetic Theory A moving puck undergoes a 2D collision on an air table with a stationary 'diatomic molecule' puck system causing rotational motion in the diatomic system (15 fps).

Rotational Molecule Collision **PRU014.MOV**

Macro Kinetic Theory A moving puck undergoes a 2D collision on an air table with a stationary 'diatomic molecule' puck system. This causes rotational motion in the diatomic system (15 fps).

2 Puck Elastic Collision 7 **PRU015.MOV**

2D Motion A fast puck undergoes a head on elastic collision with a slow puck on an air table (30 fps).

2 Puck Inelastic Collision 5 **PRU016.MOV**

2D Motion A fast puck on an air table undergoes an inelastic collision at about a 90° angle with a slow puck (30 fps).

2 Puck Inelastic Collision 6 **PRU017.MOV**

2D Motion A fast moving puck on an air table collides inelastically with a slow moving puck (10 fps).

2 Puck Elastic Collision 8 **PRU018.MOV**

2D Motion A moving puck on an air table collides elastically with more massive stationary puck. After colliding, the pucks move at almost a 90° angle with respect to each other (30 fps).

2 Puck Inelastic Collision 7 **PRU019.MOV**

2D Motion A moving puck undergoes a head-on, inelastic collision on an air table with a more massive stationary puck (15 fps).

3 Shape Elastic Collision 1 **PRU020.MOV**

2D Motion A moving U-shape, triangle and circle collide elastically on an air table (10 fps).

3 Shape Elastic Collision 2 — **PRU021.MOV**

2D Motion A moving U-shape, triangle and circle collide elastically on an air table (10 fps).

Puck-Triangle Elastic Collision — **PRU022.MOV**

2D Motion A moving puck collides elastically on an air table with a stationary triangle causing the triangle to undergo rotational motion. This demonstrates angular momentum conservation (10 fps).

4 Shape Elastic Collision 1 — **PRU023.MOV**

2D Motion A moving U-shape, triangle, circle and puck collide elastically on an air table causing rotational motions. This demonstrates angular momentum conservation (15 fps).

4 Shape Elastic Collision 2 — **PRU024.MOV**

2D Motion A moving circle collides elastically with a stationary U-shape, triangle, and puck on an air table causing rotational motions. This demonstrates angular momentum conservation (10 fps).

U-Triangle Elastic Collision 1 — **PRU025.MOV**

2D Motion A moving triangle collides elastically with a spinning stationary U-shape on an air table. This causes rotational motions and demonstrates angular momentum conservation (15 fps).

U-Triangle Elastic Collision 2 — **PRU026.MOV**

2D Motion A moving triangle collides elastically with a moving U-shape on an air table. After the collision, the objects are both spinning and undergo rotational motions. This demonstrates angular momentum conservation (30 fps).

U-Triangle Elastic Collision 3 — **PRU027.MOV**

2D Motion A moving triangle collides elastically with a spinning stationary U-shape on an air table. After the collision, the objects are both spinning and undergo rotational motions. This demonstrates angular momentum conservation (10 fps).

Puck-Elastic Bar Collision 1 — **PRU028.MOV**

2D Motion A moving puck collides elastically on an air table with a stationary bar off center causing rotational motion and demonstrating angular momentum conservation (10 fps).

Puck-Elastic Bar Collision 2 — **PRU029.MOV**

2D Motion A moving puck collides elastically on an air table with a stationary bar off center causing rotational motion and demonstrating angular momentum conservation (15 fps).

Puck-Elastic Bar Collision 3 — **PRU030.MOV**

2D Motion A moving puck collides elastically on an air table with a stationary bar. The collision is off center and causes rotational motion that demonstrates angular momentum conservation (15 fps).

Puck-Elastic Bar Collision 4 — **PRU031.MOV**

2D Motion A moving puck collides elastically on an air table with a stationary bar on center demonstrating angular momentum conservation (15 fps).

Puck-Elastic Bar Collision 5 — **PRU032.MOV**

2D Motion A moving puck collides elastically on an air table with a spinning stationary bar causing rotational motion and demonstrating angular momentum conservation (15 fps).

Adiabatic One Puck Collisions 1 — **PRU033.MOV**

Macro Kinetic Theory A single puck undergoes 2D motion as it bounces off vibrating air table walls. This emulates adiabatic molecular motion in a 2D box (6 fps).

Adiabatic One Puck Collisions 2 — **PRU034.MOV**

Macro Kinetic Theory A single puck undergoes 2D motion as it bounces off vibrating air table walls. This emulates adiabatic molecular motion in a 2D box (6 fps).

Adiabatic Many Puck Collisions 1 — **PRU035.MOV**

Macro Kinetic Theory A large grey puck collides with 42 small red and black pucks on an air table with vibrating walls. This movie can be used for the study of velocity distributions and mean free path (10 fps).

Adiabatic Many Puck Collisions 2 — **PRU036.MOV**

Macro Kinetic Theory A large grey puck collides with 42 small red and black pucks on an air table with vibrating walls. This movie can be used for the study of velocity distributions and mean free path (10 fps).

Adiabatic Many Puck Collisions 3 — **PRU037.MOV**

Macro Kinetic Theory A large grey puck collides with 42 small red and black pucks on an air table with vibrating walls. This movie can be used for the study of velocity distributions and mean free path (10 fps).

Adiabatic Many Puck Collisions 4 — **PRU038.MOV**

Macro Kinetic Theory A large grey puck collides with 42 small red and black pucks on an air table with vibrating walls. This movie can be used for the study of velocity distributions and mean free path (10 fps).

Entropy 1 **PRU039.MOV**

Macro Kinetic Theory Sixteen red pucks mix and collide with sixteen grey pucks of the same mass on an air table with vibrating walls. This demonstrates entropy increase. One puck is marked for mean free path studies (10 fps).

Entropy 2 **PRU040.MOV**

Macro Kinetic Theory Sixteen red pucks mix and collide with sixteen grey pucks of the same mass on an air table with vibrating walls. This demonstrates entropy increase. One puck is marked for mean free path studies (10 fps).

Entropy 3 **PRU041.MOV**

Macro Kinetic Theory Sixteen red pucks mix and collide with sixteen grey pucks of the same mass on an air table with vibrating walls. This demonstrates entropy increase. One puck is marked for mean free path studies (10 fps).

Spiraling Puck 1 **PRU042.MOV**

Rotational Motion A rotating puck tethered to a center post spirals inward on an air table as a string providing a central force wraps around the post and becomes shorter (10 fps).

Spiraling Puck 2 **PRU043.MOV**

Rotational Motion A rotating puck on an air table spirals inward at an increasing angular velocity as a string providing a central force is pulled inward through a hole in the center of the table (10 fps).

Spiraling Puck 3 **PRU044.MOV**

Rotational Motion A rotating puck on an air table spirals inward at an increasing angular velocity as a string, providing a central force, is pulled inward through a hole in the center of the table (10 fps).

The University of Maryland Traveling Wave Movies

Triangular Wave Pulse Propagation **UMD001.MOV**

Wave Motion A triangular-shaped transverse wave moves along a stretched spring (30 fps).

Rounded Wave Pulse Propagation **UMD002.MOV**

Wave Motion A rounded transverse wave moves along a stretched spring (30 fps).

Waves w/ Different Amplitudes **UMD003.MOV**

Wave Motion Two transverse waves with different amplitudes move along two identical springs stretched by the same amount (30 fps).

Waves Traveling w/ Different Tensions **UMD004.MOV**

Wave Motion Two transverse waves move along on springs of different tensions (30 fps).

Waves Traveling w/ Different Shapes **UMD005.MOV**

Wave Motion Two transverse waves with different shapes move along two identical springs stretched by the same amount (30 fps).

Constructive Wave Interference **UMD008A.MOV**

Wave Motion Two transverse waves, moving in the opposite direction along the same spring, pass through each other causing momentary constructive interference (30 fps).

Transverse Wave Reflections **UMD008B.MOV**

Wave Motion Transverse waves move along two identical springs stretched by the same amount. One wave reflects from a free end and the other from a fixed end (30 fps).

Destructive Wave Interference **UMD009.MOV**

Wave Motion Two transverse waves, moving in opposite directions on the same stretched spring, pass through each other and undergo momentary destructive interference (30 fps).

Triangular Wave on a Tagged Spring **UMD011.MOV**

Wave Motion One triangular transverse wave moves along a stretched spring that is marked at intervals of 10cm (30 fps).

Rounded Wave on a Tagged Spring **UMD012.MOV**

Wave Motion One rounded transverse wave moves along a stretched spring that is marked at intervals of 10cm (30 fps).

Gaussian Wave on a Tagged Spring **UMD013.MOV**

Wave Motion One 'Gaussian' pulse moves along a stretched spring that is marked at intervals of 10cm (30 fps).

A Wave Encounters Two Mediums 1 **UMD014A.MOV**

Wave Motion A transverse wave pulse travels from a high-mass density spring to low-mass density spring and experience partial reflections and transmissions (30 fps).

A Wave Encounters Two Mediums 2 **UMD014B.MOV**

Wave Motion A transverse wave pulse travels from a low-mass density spring to high-mass density spring and experience partial reflections and transmissions (30 fps).