Video Encyclopedia of Physics Demonstrations

Here is a list of those video demonstrations I have found particularly interesting and instructive. Textbooks are: CJ = Cutnell and Johnson fourth edition; HRK = Halliday, Resnick, and Krane extended second edition; RC = Roberson and Crowe sixth edition. End-of-chapter questions are denoted by a "Q," end-of-chapter problems by a "P," and in-text examples by an "E" followed by the chapter number.

<u>Demo 01-14 "Guinea and Feather"</u>
A similarly shaped paper disk and metal disk are dropped side by side both before and after pumping the air out of the tube to show that air resistance is what keeps them from hitting the bottom simultaneously.

Suggested method of use: Freeze the video after the vacuum pump is turned on and ask the students to predict the outcome when the tube is now inverted.

where we teach this: 1D Kinematics in Physics I
textbook references: CJ Fig. 2.18; HRK Sec. 2-8

<u>Demo 01-18 "Dropped Slinky"</u>
A slinky is held at one end with the other end freely hanging. If it is released from rest, will the free end initially accelerate upward or downward? Slow-motion footage reveals that the free end initially remains motionless, and the slinky collapses down to its rest length.

Suggested method of use: Play the video and then ask the students to explain why the lower end initially remains motionless. The answer is related to the fact that at each point along the spring the tension supports the weight below that point.

where we teach this: speed of waves on a string in Physics I
textbook references: CJ Q16.6; HRK P19.22

<u>Demo 01-19 "Candle in Dropped Jar"</u>
A candle is placed inside a sealed jar containing enough air to burn for a while. If the jar is dropped, what happens to the candle? Slow-motion footage reveals that the candle immediately goes out because there are no longer any convection currents to bring fresh oxygen to the flame.

Suggested method of use: Play the video and then ask the students to explain why there are no longer any convection currents. The answer is that in the frame of the jar, apparent weightlessness occurs so that $g = 0$, and hence the buoyant force is zero: warm gases no longer rise.

where we teach this: natural convection in Physics I
textbook reference: CJ Sec. 13.1

Demo 02-02 “Monkey Gun”

The classic demonstration of the monkey and the hunter.

Suggested method of use: Play the video and then ask the students as a group or homework problem to prove that the bullet will strike the monkey. To make this tractable, I suggest using real numbers. Here is an actual problem I assigned on a recent Physics I exam broken down into easy steps.

A hunter in a forest spots a monkey hanging from a tree 11 m above his position. The hunter is 56 m from the base of the tree. He quickly aims his rifle and shoots a bullet with a muzzle velocity of 110 m/s. At the instant he fires, the monkey lets go and drops toward the ground.

(i) At what angle must his gun barrel be aimed above the horizontal to hit the monkey? _______°

In the next three parts, we will prove that at this angle the monkey does get shot. Show all work in each step below.

(ii) How long after being fired does the bullet cross the monkey’s path?

(iii) How far above the hunter’s position is the monkey at that time?

(iv) Now show that the bullet has risen that same distance vertically into the air and therefore hits the monkey.

where we teach this: 2D kinematics in Physics I
textbook references: CJ P3.47; HRK p. 59

Demo 02-04 “Vertical Gun on Accelerated Car”

A free-rolling cart has a spring-loaded gun which launches a ball perpendicular to the cart. In the first experiment, the cart rolls down an inclined plane. Will the ball land ahead of or behind the gun? The answer is it lands back in the gun. In the second experiment, the cart is accelerated along a horizontal surface using a string attached to a weight hanging over the edge of the table. This time where will the ball land? It lands behind the cart.

Suggested method of use: Play the video and ask the students to guess what will happen at the two stopping points in the movie, after the appropriate questions are asked.

where we teach this: independence of x and y motion in 2D kinematics in Physics I
textbook references: CJ E3.4; HRK Fig. 4.7

Demo 02-11 “Local Vertical with Acceleration”

A liquid accelerometer is equivalent to a carpenter’s level. What will it read if attached to a cart gliding down a frictionless inclined plane?

Suggested method of use: Play the video and ask the students to guess what will happen at the stopping point in the movie, after the above question is asked. The cart experiences apparent weightlessness along the direction of the incline and hence the accelerometer reads level.

where we teach this: weightlessness in freefall in Physics I
textbook references: CJ p. 102; HRK p. 87

Demo 02-13 “Inertia Ball”
The classic demonstration of a heavy mass connected by a rope to a rigid ceiling. A second, identical rope hangs freely from the bottom end of the mass. What happens if we pull gently on the free hanging rope? Same question if we pull with a quick jerk?

Suggested method of use: Play the video and then ask the students to explain the results. A free-body diagram helps.

where we teach this: inertia in Physics I
textbook references: CJ Q4.3; HRK Q5.2

Demo 02-23 “Water Rocket”
The usual kid’s toy. Air is pumped into a small rocket and released. The rocket is found to reach great heights if half filled with water but barely rises if full of air alone, even if pumped twice as much to keep the pressure increase the same in both experiments.

Suggested method of use: Play the video and ask the students to explain the results. The key is to note that the water escapes with the extra air, carrying significant momentum with it.

where we teach this: completely inelastic collisions in Physics I
textbook references: CJ E7.7; HRK p. 213

Demo 03-06 “Stability of Rolling Car”
Either the front or the rear axle on a hot wheels car can be locked. In which case will the car stably descend an inclined plane? The answer is only if the front axle is locked.

Suggested method of use: Play the video and ask the students to explain the results. The key is to note that the coefficient of static friction (applicable to the rear wheels since they are rolling without slipping in the stable case) is larger than the coefficient of kinetic friction (applicable to the front wheels since they are locked) and hence the rear wheels lag behind. This means cars must be designed to provide most of the braking at the front wheels.

where we teach this: rolling without slipping in Physics I
textbook references: CJ E8.9; HRK p. 259

Demo 03-24 “Double Cone on Incline”
A double cone appears to roll uphill on rails which spread apart. This spread means that the center of gravity actually lowers, as physics demands.

Suggested method of use: Stop the video before it explains the result and ask the class to provide it.

where we teach this: center of gravity in Physics I
textbook reference: HRK Sec. 14-4

Demo 03-26 “Toppling Cylinders”
A symmetric right cylinder topples when its cap is removed. The secret is that there are two balls inside it.

Suggested method of use: Play the video and ask the students to draw a free-body diagram which explains the results. I already gave you a handout explaining this in great detail.

where we teach this: second condition for static equilibrium in Physics I
textbook references: CJ Sec. 9.2; HRK P14.18

Demo 04-05 “Pulley and Scales”
A pulley is attached to the bottom of a spring scale mounted in a frame that in turn hangs from an upper spring scale. The weight of the frame and its contents is 5 N as read on the upper scale. When the free end of the rope is pulled until the lower scale reads 10 N, what will the upper scale read? The counterintuitive answer is 10 N.

Suggested method of use: Play the video and ask the students to guess the result. After viewing the answer, explain it by drawing a clear free-body diagram.

where we teach this: mechanical advantage of pulleys in Physics I
textbook references: CJ E4.20; HRK P5.67

Demo 04-15 “Meter Stick on Fingers”
Balance a meter stick horizontally on two fingers and then move your fingers toward each other. The stick will remain balanced and your fingers will meet under its center of mass even if:
(i) your two fingers don’t start symmetrically disposed about the center point; (ii) your fingers have quite different coefficients of friction; and (iii) you shift the center of mass off-center by placing a weight on one end of the stick.

Suggested method of use: Play the video and ask the students to explain the results. A free-body diagram helps.

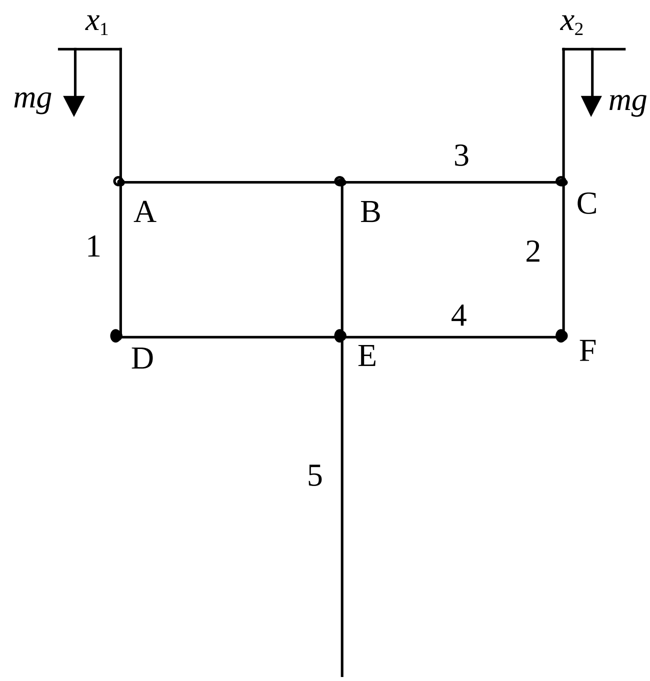
where we teach this: conditions for static equilibrium in Physics I
textbook references: CJ P9.11; HRK E14.1

Demo 04-17 “Roberval Balance”
A single-arm pan balance attains neutral equilibrium for two equal weights only if they are equidistant from the pivot point; a double-arm pan balance works regardless of where on the two pans you place the weights.

Suggested method of use: Play the video and ask the students to explain the results by guiding them through the following analysis.

The single-arm pan balance is equivalent to a meter stick pivoted about its center. Prove that two equal weights will balance only if they are equidistant from the center.

The double-arm balance is sketched below. It consists of five rigid pieces (labeled 1–5) joined by six pins (labeled A–F). Suppose a mass m is on the left-hand pan a distance x_1 to the left of its pole support and similarly a mass m is on the right-hand pan a distance x_2 to the right of its pole support.



Balance the torques about pin D to find the horizontal force on rod 1 at pin A in terms of the vertical distance d between rods 3 and 4. Then use Newton's third law to find the horizontal force on rod 3 at pin A. Similarly find the horizontal forces on rods 1 and 4 at pin D by balancing the torques at pin A. Repeat both of these steps at pins C and F. Finally, find the horizontally forces that rod 5 must exert on rods 3 and 4 at pins B and E, respectively, in order to balance the system.

The above proves that static equilibrium can be achieved. Note that by Newton's third law there are horizontal forces on rod 5 at pins B and E. Find expressions for them and use that to explain your answers to the following two questions:

(i) If rod 5 were attached to the ground by a pin, would the system balance?

(ii) If rod 5 were attached to a nonpivoting roller on flat ground, would the system balance?

For extra credit, prove that balance cannot be achieved if the two weights have unequal masses m_1 and m_2. To do this, first balance the torques about pin B to find a relation between the vertical forces on rod 3 at pins A and C. (Assume that the horizontal distance between rods 5 and 1 is that same as that between rods 5 and 2.) Do likewise about pin E to relate the vertical forces on rod 4 at pins D and F. Now use Newton's third law to find expressions for the net vertical forces on rods 1 and 2 and show that it is impossible to make both of them zero.

where we teach this: static equilibrium about frame pins in Engineering Mechanics
textbook reference: Beer & Johnston sixth edition Sec. 6.11

<u>Demo 05-20 "Roundup"</u>
The classic demonstration of how someone can stick to the inner wall of a spinning cylinder at an amusement park.

Suggested method of use: Play the video and then ask the students to solve the problem in their textbook listed below.

where we teach this: uniform circular motion in Physics I
textbook references: CJ P5.58; HRK P6.53 (after reading p. 110)

<u>Demo 06-06 "Bike Wheel on Incline"</u>
The axle can be either locked or unlocked on a bike wheel. When locked, the axle rolls down a pair of inclined rails much more slowly than when unlocked, because the wheel then has rotational kinetic energy.

Suggested method of use: Play the video and ask the students to guess what will happen at the stopping point in the movie.

where we teach this: combined translational and rotational motion in Physics I
textbook references: CJ p. 259; HRK Sec. 12-6

<u>Demo 06-09 "Loop the Loop"</u>
A marble is rolled down a track with a loop the loop at the bottom. From what height must it be released to just make it around the loop?

Suggested method of use: Play the video and then ask the students to determine the required height above the topmost point of the loop in terms of the radius R of the loop. If the ball slides without rolling, the answer is $0.5R$; if the balls rolls without slipping, the answer is $0.7R$. <u>Hints</u>: What is the centripetal force if the normal force exerted by the track on the ball at the top of the loop is zero? Solve for mv^2 and plug into the expression for conservation of mechanical energy between the release point and this topmost loop point.

where we teach this: vertical circular motion in Physics I
textbook references: CJ Sec. 5.7; HRK P12.50

Demo 06-10 “Penny Drop Stick”
A meter stick is pivoted at one end. It is held horizontally and its top surface is lined with pennies. It is then released. The pennies along the two thirds of the stick nearest the pivot are observed to remain on the stick, while the remaining pennies lift off the surface in a straight line, making a sharp corner, because the outer third of the stick falls with an acceleration greater than g.

Suggested method of use: Play the video and then ask the students to prove that for small angles from the horizontal the tangential acceleration of a point in the stick is linearly proportional to the distance of that point from the pivot, reaching the value of g at two-thirds of the length. Hint: Use the rotational analog of Newton’s second law applied to the entire rod at the instant of release.

where we teach this: rotational analog of Newton’s second law in Physics I
textbook references: CJ Sec. 9.4 (also see P8.38); HRK Fig. 11.10

Demo 07-09 “Satellite Derotator”
A uniform spinning disk of mass M and radius R has two small weights of mass m clipped to its perimeter, one at each end of a diameter for stability. These small weights can be released while the disk is spinning, but are connected to its center by rope tethers of length L. By correctly choosing these masses and dimensions, all of the angular momentum of the disk can be transferred to the weights, so that the disk ends up at rest.

Suggested method of use: Play the video twice. The second time, freeze the situation after release and use a plastic ruler to measure directly on the screen the ratio of L to R. Now ask the students to calculate two quantities using this piece of information. Hint: Apply conservation of both angular momentum and rotational KE.

(i) The ratio of the final angular velocity of the weights to the initial angular velocity of the disk. (Answer: unity.)

(ii) The ratio of the mass of the disk to that of either weight. (Answer: about 25.)

where we teach this: conservation of angular momentum in Physics I
textbook references: CJ Sec. 9.6; HRK Sec. 13-4

Demo 08-16 “Hoops and Arcs”
A series of metal arcs which are increasingly large portions of a circle of radius R are balanced symmetrically on a knife edge. If set into small-angle oscillations, which arc will have the longest period?

Suggested method of use: Play the video and ask the students to guess the answer. After seeing the experimental result, guide the students through a theoretical proof of it, following a separate handout I gave to you.

where we teach this: physical pendulums in Physics I
textbook references: CJ Sec. 10.6; HRK Sec. 15-5 (also see P15.43)

Demo 09-06 “Glass Breaking with Sound”
Sure to be a classroom favorite. A glass beaker is shattered using high-intensity sound. Nice added touches in the video include an illustration of the phase shift between the driving wave and the singing of the glass detected with a microphone and synchronously triggered oscilloscope, and the use of a stroboscope to make visible the oscillations of the rim prior to breakage.

Suggested method of use: Play the video and discuss any details that interest you and the class such as the elastic limit, resonance, the myth of opera singers being able to do this, and so on.

where we teach this: resonance and the elastic limit in Physics I
textbook references: CJ Secs. 10.2 & 10.8; HRK Sec. 15-9

Demo 09-08 “Wilberforce Pendulum”
A mass hanging from a spiral spring has a long arm on which two weights can be slid in and out until the longitudinal and torsional modes of oscillation of the system are brought into resonance. Exciting one mode leads to the standard demonstration of motion coupling back and forth between the two. I particularly like this coupling method as it illustrates the concept of molecular vibrational-librational energy transfer of personal interest to me. The prerequisite concept of normal modes is not currently taught in any of our courses to the best of my knowledge.

Demo 09-10 “Pulse on Moving Chain”
A chain is rotated using a motor and pulley. By matching the speed of the chain to the wave speed of counter-propagating pulses with respect to the chain, pulses can appear to be motionless, analogous to Marsh’s lassoo modes.

Demos 09-21 & 09-22 “Single-Slit Diffraction & Double Slit Interference of Water Waves”
A ripple tank is used to illustrate single and double slit interference for various choices of wavelength and slit width and separation.

Suggested method of use: Play the videos during the introductory explanation of the analogous optics lab in physics II to help the students visualize these important concepts.

where we teach this: diffraction & interference in Physics II lab
textbook references: CJ Chap. 27; HRK Chaps. 45–46

Demos 09-29 & 09-30 “Drumhead & Chadni Plates”
A stroboscope is used to demonstrate a few modes of oscillation of a drumhead; I only wish they showed more. On the other hand, a large and gorgeous variety of the modes of both a square plate and a violin shape are demonstrated using sand on Chladni plates.

where we teach this: solution of the 2D wave equation in Math Physics II
textbook reference: Boas second edition Sec. 13.6

Demo 10-09 “Siren in Vacuum”
A siren with a flashing light is suspended in an evacuated bell jar to show that light but not sound travels in a vacuum.

Suggested method of use: Ask the students to guess the result before the video is played. Follow up with a discussion of typical movie scenes of science fiction space battles.

where we teach this: wave media in Physics II
textbook references: CJ p. 735; HRK p. 417

Demo 10-14 & 10-16 “Sound in Helium & Vocal Formants”
The first video demonstrates that an organ pipe emits a higher pitch when filled with helium compared to air. The second video uses a spectrum analyzer to show the rich variety of frequencies present when letters are spoken. Together, these two clips can be used to explain why the man’s voice sounds funny on the first clip when he inhales helium, as explained in a handout I have previously given to you.

Suggested method of use: Play the video and then ask the students for the above explanation. Be sure to bring up the fact that our vocal chords are analogous to guitar strings.

where we teach this: standing waves on strings and pipes in Physics I
textbook references: CJ Secs. 17.5–17.7; HRK Sec. 20-5

Demo 10-21 “Doppler Effect”
A speaker emitting a tone is spun in a circle. An animation helps explain the crowding of the waves in the forward going direction.

Suggested method of use: Play the video before introducing the discussion of the classical Doppler effect and ask the students to qualitatively explain the results.

where we teach this: Doppler effect for sound in Physics I
textbook references: CJ Sec. 16.10; HRK Sec. 20-7

Demo 11-12 “Magdeburg Hemispheres”
The classic demonstration of the fact that it requires great force to pull apart two hemispheres when the space between them is evacuated. A brief animation helps picture the pressure forces.

Suggested method of use: Play the video and ask the students to calculate how much weight must be suspended from the lower hemisphere to break the seal.

OR <u>Demo 11-15 “Vacuum Bazooka”</u>
A tight-fitting ball is placed inside a copper pipe and rubber sheets cap both ends. The pipe is then evacuated. When one of the sheets is knocked off, the ball shoots out of the other end. A brief animation helps picture the pressure force.

Suggested method of use: Stop the video before the sheets are knocked off and ask the students which sheet must be knocked off to get the ball to fly out of the left end of the pipe.

OR <u>Demo 11-16 “Barrel Crush”</u>
Water is boiled inside a 55-gallon drum and then sealed and cooled with ice. At a certain point, the reinforced barrel dramatically collapses.

Suggested method of use: Play the video and then ask the students to calculate by what factor the volume of water is smaller than the same mass of steam.

OR <u>Demo 11-17 “Air Pressure Lift”</u>
A woman stands on a board atop two deflated hot water bottles connected to a tube. What gauge pressure must be applied to the tube to lift the woman?

Suggested method of use: Ask the students to guess whether lung power suffices when the video asks the above question. After the film is entirely viewed, ask the students to estimate the required gauge pressure by guestimating the woman’s weight and the area of the board she stands on. Express the answer in terms of the length of a vertical straw full of water that would have to be blown out to require the same lung power. (Answer: about 10 cm.)

OR <u>Demo 11-18 “Inertia Shingles”</u>
Half of the length of a thin board extends over the edge of a horizontal table. By placing a single sheet of newspaper over the end on the table, atmospheric pressure exerts enough downward force to keep it in place while a karate chop to the other end breaks it off.

Suggested method of use: Ask the students to guess whether it is possible before playing the video.

where we teach this: fluid pressures in Physics I
textbook reference: CJ Secs. 11.2–11.3

<u>Demo 12-02 “Pressure vs. Depth”</u>
A pressure sensor consisting of a vertical array of LEDs nicely illustrates that the pressure in a liquid column is directly proportional to the depth. What will happen if the column is tipped at a steep angle?

Suggested method of use: Play the video and ask the students to guess the answer when the video stops at the above question.

where we teach this: dependence of fluid pressure on depth in Physics I
textbook reference: CJ Sec. 11.3

Demo 12-06 “Water and Mercury U-tube”
Water is poured into one arm of a u-tube filled with mercury. Close-up shots of a ruler allows measurement of the air-water, water-mercury, and mercury-air levels.

Suggested method of use: Play the video and freeze at the above shots and write down the measurements. Then ask the class to use these data to calculate the specific gravity of mercury. Note that the ruler is not aligned with the bottom of the u-tube, but that does not matter because only the differences in levels are needed for this exercise.

where we teach this: manometers in Physics I
textbook reference: CJ Sec. 11.4 (also see P11.30)

Demo 12-11 “Buoyant Force”
A frame is arranged with two spring scales so that the weight of a beaker of a water and the apparent weight of a block lowered into the beaker can be separately measured. The loss of apparent weight of the block is exactly equal to the gain in weight of the beaker.

OR Demo 12-12 “Archimedes’ Principle”
A block and bucket are suspended from a spring scale. The block is lowered into a brimming beaker and the overflow water is collected in a beaker. If this excess water is poured into the bucket, the spring scale returns to the air weight of the block.

Suggested method of use: Play either video and ask the students to predict the results at the stopping point.

where we teach this: Archimedes’ principle in Physics I lecture & lab
textbook reference: CJ Sec. 11.6

Demo 12-21 “Helium Balloon in Liquid Nitrogen”
When a balloon filled with helium is cooled to 77 K, the helium remains a gas but its density decreases to the point that the balloon no longer floats.

Suggested method of use: Play the video and ask the students to calculate at what temperature the balloon would no longer float if the balloon skin had neither mass nor elasticity. Hint: Rewrite the ideal gas law in terms of density. (Answer: about 40 K.)

where we teach this: Archimedes’ principle and the ideal gas law in Physics I
textbook reference: CJ E11.10 and Sec. 14.2

Demo 13-03 “Curve Balls”
A light styrofoam ball and throwing tube exhibits dramatic curving. A convincing animation explains the effect.

where we teach this: Magnus effect in Fluid Mechanics
textbook references: RC Fig. 11.15; CJ Fig. 11.38

Demo 13-05 “Suspended Plate in Air Jet”

A radial air stream between two horizontal plates is sufficient to suspend the lower plate even if considerable weight is added to it.

where we teach this: Bernoulli’s equation in Fluid Mechanics
textbook references: RC Sec. 5.3; CJ E11.13

Demo 13-07 “Vortex Cannon”

A tube has one end covered with a flexible membrane and the other end a cap with a circular hole cut in it. The tube is filled with smoke and the membrane is tapped, generating smoke rings which can even be used to blow out a candle.

where we teach this: vortex shedding in Fluid Mechanics
textbook reference: RC Sec. 4.7

Demos 13-08 “Un-mixing”

A line of dye is injected into a layer of glycerine between two cylindrical shells. When the inner cylinder is turned, laminar flow spreads out the dye in a manner that can be undone by reversing the direction of turning. An animation helps understand the phenomenon.

where we teach this: laminar flow in Fluid Mechanics
textbook reference: RC p. 88

Demos 13-15 “Torricelli’s Tank”

Water squirts out of a series of holes along the length of a vertical column. For which hole will the water jet travel the greatest horizontal distance before striking the tabletop? The students should be asked to prove that the answer is midway along the column. Hint: Apply conservation of energy between the top of the column and a point just outside an orifice.

where we teach this: Torricelli’s theorem in Fluid Mechanics
textbook references: RC Sec. 5.3; CJ E11.15

Demo 13-16 “Accelerometers”

Two capped jars are full of water. One has a metal ball hanging from the top; the other has a float tethered to the bottom. If both jars are accelerated to the right, what will happen to the two balls?

Suggested method of use: Stop the video and ask the students to guess the results. After viewing the entire video, ask for a qualitative explanation. Hint: The buoyant force acts opposite to the apparent direction of gravity.

where we teach this: buoyant force in Physics I
textbook reference: CJ Sec. 11.6

Demo 13-17 “Paraboloid of Revolution”
When uniformly rotated, the surface of a liquid adopts a paraboloidal shape.

Suggested method of use: Play the video and then ask the students to prove the result. Here is the outline of a particularly simple derivation. Consider a drop of water of mass m at the surface of the water, a distance x from the axis of rotation and height y above its lowest point. The only two forces on the drop are the normal force and gravity. Now apply Newton’s second law and use elementary calculus to relate the derivative to the slope of the surface.

where we teach this: banked curves in Physics I; Euler’s equation in Fluid Mechanics
textbook references: CJ Sec. 5.4; HRK p. 111; RC p. 141

Demo 13-23 “Two Soap Bubbles”
A small soap bubble is connected by a tube and stopcock to a large soap bubble. What happens when the stopcock is opened?

Suggested method of use: Stop the video and ask the students to guess the result. After showing the result, ask for a qualitative explanation. There are actually two effects going on: the gauge pressure is proportional to the surface tension divided by the radius of the bubble, and the surface tension itself varies inversely with the radius because the soap film gets thinner. A similar effect occurs for balloons: it is harder to blow up a balloon when it is small than when it is big.

where we teach this: surface tension in Fluid Mechanics
textbook reference: RC Sec. 2.7

Demo 14-09 “Thermostat Model”
A bimetallic strip is arranged so that when cool it makes electrical contact and turns on a light which heats the strip, turning off the light and starting the cycle over. A thermometer shows that the temperature consequently remains within a narrow range.

where we teach this: thermal expansion in Physics I
textbook references: CJ p. 355; HRK Sec. 22-5

Demo 14-11 “Thermal Expansion”
A ball does not fit through a hole in a cool plate, but does fit through when the plate is heated.

Suggested method of use: Ask the students to guess the answer. After viewing the video, ask them to explain it.

where we teach this: thermal expansion of holes in Physics I
textbook reference: CJ E12.5

Demo 14-18 “Specific Heat with Rods and Wax”

Three equal mass metal cylinders at 100 ˚C are placed on top of wax. They melt to a depth which is proportional to the specific heats of the three metals.

Suggested method of use: View the video and then ask the students to calculate the ratio of the depths using the Dulong-Petit model of the heat capacity of solids.

where we teach this: heat capacity of solids in Thermodynamics and Modern Physics II
textbook references: Stowe Chap. 27; Beiser Sec. 9.7

Demo 14-26 “Insulation (Dewar Flasks)”

The rate of heat loss from four dewars filled with hot water is compared: one is evacuated and silvered, one is evacuated but not silvered, one is silvered but not evacuated, and the last is neither evacuated nor silvered.

Suggested method of use: Ask the students to guess the order in which they will cool.

where we teach this: heat transfer in Physics I
textbook references: CJ Fig. 13.20; HRK Sec. 25-7

Demo 15-04 “Adiabatic Expansion”

The temperature of the air in a corked bottle is graphed as the pressure is increased and subsequently blows the cork. A small amount of water in the bottom results in the formation of a fog when this happens.

Suggested method of use: Ask the students to calculate the gauge pressure in the bottle just prior to blowing the cork using the ideal gas and adiabatic laws, following the analysis in a separate handout I have given to you. A more qualitative explanation is that since the escaping air does work on the atmosphere, its internal energy and hence its temperature must drop.

where we teach this: adiabatic expansion of an ideal gas in Thermodynamics
textbook references: Stowe Secs. 14.D & 23.D; CJ Secs. 12.10 & 15.5; HRK p. 558

Demo 15-13 “Freezing by Boiling”

When the pressure above a sample of water in a bell jar is reduced, the water first boils and then freezes.

Suggested method of use: After viewing the video, ask the students to explain why the water boils by considering a pressure-temperature diagram. Next, pointing out that this removes the latent heat of vaporization from the remaining water, explain why it freezes. The video claims that if the pressure is greatly reduced, water can both boil and freeze at around 0 ˚C. Near what special pressure will this occur? (Answer: at the triple point pressure of 4.58 torr.)

where we teach this: phase changes in Physics I
textbook reference: CJ Sec. 12.9

Demo 15-16 “Regelation”

A wire bearing a heavy weight is hung over an ice cube. In a few minutes, the wire cuts through the ice, yet the cube remains intact.

Suggested method of use: After viewing the video, ask the students to explain how the wire is able to cut through the ice even though the cube’s temperature always remains below 0 ˚C, by considering a pressure-temperature diagram. Since the ice never warms up, it quickly refreezes behind the wire. This concept helps explain the motion of glaciers but is not a correct explanation of how ice-skating works.

where we teach this: phase changes in Physics I
textbook reference: CJ Fig. 12.33(b)

Demo 15-18 “Sublimation of Carbon Dioxide”

A balloon full of CO_2 is immersed in liquid nitrogen to freeze it. The balloon is then cut open and the solid carbon dioxide poured out. The solid is observed to sublime without ever liquefying.

Suggested method of use: After viewing the video, ask the students to explain how this can occur by considering a pressure-temperature diagram.

where we teach this: phase changes in Physics I
textbook reference: CJ p. 368

Demo 16-05 “Equipartition of Energy Simulation”

Two sizes of metal balls are placed on a shaking table. Since all balls have the same average kinetic energy, the smaller balls have a higher average speed.

Suggested method of use: Play the video and ask the students to calculate the ratio of average speeds if the smaller balls have say one-quarter of the mass of the larger balls. Does the answer depend on whether the balls roll or slip? (Answer: no, the speeds of both size balls will decrease by the same fractional amount if they roll instead of slipping.)

where we teach this: equipartition in Thermodynamics
textbook reference: Stowe Chap. 5

Demo 16-08 “Brownian Motion Simulation”

Metal balls are placed on a shaking table. A sliding disk is observed to jostle around in a manner characteristic of Brownian motion.

Suggested method of use: Ask the students to explain Brownian motion before playing the video. Afterward, be sure to discuss the fact that in reality it takes about 10,000 air molecules striking one side of a smoke particle to get it to move, not the single collisions the demo might lead one to believe.

where we teach this: kinetic theory of ideal gases in Physics I
textbook references: CJ Sec. 14.3; HRK Sec. 24-5

Demo 16-24 "Electrostatic Ping-Pong Balls"
A ping-pong ball coated with conducting paint energetically bounces between the plates of a large parallel-plate capacitor connected to a Wimshurst machine. An animation helps explain how the ball rapidly transfers charge between the plates, so that the bouncing stops when the Wimshurst is shut off.

Suggested method of use: Play the video and freeze it prior to the animation. Ask the students to explain the effect and explain whether it is necessary to keep cranking the Wimshurst.

where we teach this: electrostatic forces in Physics II
textbook references: CJ Chap. 18; HRK Chap. 27

Demo 17-03 "Electrophorus"
An acrylic sheet is charged by rubbing it with wool. A metal plate is then placed on the sheet and grounded momentarily. If the plate is now lifted off the acrylic and brought near a second metal plate that is grounded, a spark jumps between the plates. The process can be repeated several times without recharging the acrylic. An animation explains how the charging process occurs.

Suggested method of use: Play the video and then carefully review each step in the process.

where we teach this: charging by contact and by induction in Physics II
textbook reference: CJ Sec. 18.4

Demo 17-05 "Kelvin Water Dropper"
Electric charges are built up triboelectrically from the energy of falling drops of water. An animation explains how the process works.

where we teach this: electrostatic charging in Physics II
textbook reference: CJ Secs. 18.2–18.4

Demo 17-11 "Lightning Rod"
A model house and charged cloud are used to demonstrate that a lightning rod prevents the large sparks that occur in its absence.

Suggested method of use: Play the video and then ask the students how the lightning rod works. Hints: Air breaks down when the electric field rises to 3 kV/mm. The distance from the cloud to the house is fixed. Visible sparks only occur if the potential difference between the cloud and house is high enough that electrons traveling along the path of ionization acquire sufficient energy between collisions to excite the electrons in air molecules to high enough energy levels.

where we teach this: corona discharge in Physics II
textbook reference: HRK p. 666

Demos 17-12 & 17-13 "Pinwheel & Point and Candle"
Sharp points at a high voltage can produce an electrostatic sprinkler, as well as an electric wind which can blow out a candle. An animation helps shows that these effects are *not* based on a rocket-like spray of electrons, but instead on the ionization and subsequent repulsion of adjacent air molecules.

Suggested method of use: Play the videos and then carefully discuss what is happening.

where we teach this: corona discharge in Physics II
textbook reference: HRK p. 666

Demo 17-15 "Faraday Ice Pail"
A metal bucket is charged up using a Wimshurst machine. A metal ball is scraped on different parts of a pail and contacted to a foil electrometer, showing that the charge resides only on the outer surface of the pail.

Suggested method of use: Ask the students to guess where the charge resides before playing the video.

where we teach this: electrostatic shielding in Physics II
textbook references: CJ Sec. 18.8; HRK Sec. 29-4

Demo 18-25 "Dissectible Capacitor"
A cylindrical capacitor with a glass dielectric is charged up and disassembled. The metal plates are then neutralized by touching them together, with no visible spark. Nevertheless, when the capacitor is reassembled and a rod nearly shorts the two plates, a large spark is observed. Thus, charge must have been transferred from the plates to the glass and back, perhaps by corona discharge or by rubbing.

Demo 18-29 "Relaxation Oscillator"
A series *RC* circuit is constructed with a neon bulb wired across the capacitor, so that it flashes at regular intervals. Increasing either the resistance or capacitances slows down the flash rate.

Suggested method of use: Play the video and then have the students solve the problem below.

where we teach this: *RC* circuits in Physics II lecture & lab
textbook references: CJ P20.100; HRK P33.53

Demo 19-06 "Lowest Energy Configuration"
Small magnets floating in a circular dish surrounded by a coil arrange themselves in various geometrical patterns. Between 1 and 6 magnets are floated in succession with and without the

coil on. This is related to the topic of crystal structures in solid-state physics which we do not teach.

Demo 19-25 “Curie Temperature Wheel”

One edge of a metal wheel passes through the arms of a horseshoe magnet. An arc lamp is focused onto the surface just above the magnet, heating the metal above its Curie temperature. The cooler section below is then magnetically attracted, causing the wheel to rotate.

Suggested method of use: Play the video and then discuss what factors determine how fast the wheel will rotate.

where we teach this: temperature dependence of ferromagnetism in Physics II
textbook reference: HRK p. 813

Demo 20-01 “Jumping Wire”

A current-carrying wire jumps out of a horseshoe magnet.

Suggested method of use: Ask the students to predict what will happen if the magnet’s orientation is reversed when the video pauses.

where we teach this: magnetic force on a current in Physics II lecture & lab
textbook references: CJ Sec. 21.5; HRK Sec. 34-5

Demo 20-06 “Ion Motor”

A current flows radially in a copper sulfate solution between two concentric conductors. A bar magnet within the central conductor produces a field perpendicular to the plane of the liquid surface. Consequently, the fluid begins to rotate.

Suggested method of use: Pause the video and ask the students to predict what will happen to the sense of rotation if the directions of the current and/or magnet are reversed.

where we teach this: dc motors in Physics II
textbook reference: CJ Figs. 21.21(c) & 21.25(a)

Demo 20-16 “Current-Coupled Pendula”

Two coils wired in series are constrained to oscillate as pendula through the poles of two horseshoe magnets. When one coil is set into oscillations, the induced currents produce a magnetic force on the second coil which sets it into oscillation with a direction of swing which depends on the relative orientation of the two magnets.

Suggested method of use: Pause the video and ask the students to predict what will happen if the two wires joining the coils are shorted together. (Answer: magnetic braking.)

where we teach this: motional emf in Physics II
textbook references: CJ Sec. 22.2; HRK Sec. 36-4

Demo 20-21 “Induction Coil”

The primary of a transformer is connected to a dc source via a magnetic make-and-break switch. The varying field induces a large voltage in the secondary producing discharges analogous to those made by spark plugs in a car.

Suggested method of use: View the video and then demonstrate the tuning-fork vibrator found in the department.

where we teach this: transformers in Physics II
textbook references: CJ Sec. 22.9; HRK Sec. 39-5

Demo 20-24 “Eddy Current Pendulum”

A pendulum bob swings through the poles of a horseshoe magnet. Various bobs are tried: a copper disk, a wooden disk, and a copper ring at both room and liquid-nitrogen temperatures.

Suggested method of use: Ask the students to guess the order in which these bobs will be braked.

where we teach this: eddy current magnetic braking in Physics II
textbook references: CJ Q22.3; HRK p. 787

Demo 20-25 “Arago’s Disc”

A bar magnet is mounted parallel to the surface of a rotating metal disk and can spin on the same axis as it. When the disk is spun, induced currents exert a force on the magnet, causing it to rotate. An animation is used to show how a speedometer is constructed based on this concept.

Suggested method of use: View the video and then construct a diagram which shows how the force on the magnet develops so that it rotates in the same direction as the disk. Hints: Consider one electron in the metal disk just under the north pole of the magnet and another just under the south pole. In which direction are the magnetic forces on these moving charges? Consequently sketch the induced current. Now use the right-hand rule to find the direction of the induced magnetic field at the position of the permanent magnet. Thus, in what direction is the force on the bar magnet?

where we teach this: electromagnetic induction in Physics II
textbook references: CJ Secs. 22.1–22.2; HRK Sec. 36-4

Demo 20-27 “Electromagnetic Can Breaker”

Another sure classroom pleaser. A coke can is split in half and shot violently in two directions out of a coil through which a capacitor is suddenly discharged.

Suggested method of use: View the video and then construct a diagram which shows how the tensile forces on the can develop. Hints: Consider a side view. Sketch the external current running out of the board above the can and into the board below the can, say. Consquently sketch a magnetic field line curving down counter-clockwise through the can and around the top part of the coil. Next, use Lenz's law to sketch the opposing induced currents in the walls of the can. Finally use the right-hand rule to find the forces produced at various horizontal positions on the induced currents by the external field.

where we teach this: Lenz's law in Physics II
textbook references: CJ Sec. 22.5; HRK Sec. 36-3

<u>Demo 21-02 "Inductor with Lamp on AC"</u>
An inductor and ordinary light bulb are wired in series to 110 VAC. When an iron core is inserted into the coil, the bulb dims.

Suggested method of use: Play the video and ask the students to explain the effect using the equations of *RLC* ac circuits. Next ask them whether a variable inductor or a variable resistor would make a better dimmer switch for a chandelier. <u>Hint</u>: Compare the average powers dissipated in an inductor and a resistor.

where we teach this: ac circuits in Physics II lecture & lab
textbook references: CJ Sec. 23.3 (also see Q23.3); HRK Sec. 39-4

<u>Demo 21-06 "Tesla Coil"</u>
A transformer charges up a capacitor which causes a spark gap to break down thousands of times a second. The resulting pulsed voltage feeds a high-step-up transformer, producing large ac voltages at high frequencies. This is used to drive sparks across a large gap, light a fluorescent bulb inductively, and is even safely transmitted through a person by the skin effect.

where we teach this: transformers & dielectric breakdown in Physics II
textbook reference: HRK Secs. 31-5 & 39-5

<u>Demo 21-23 "Hinged Mirrors"</u>
Two plane mirrors are hinged together so they make an angle θ with respect to each other. A small light bulb is placed along a line bisecting this angle. How many bulbs (both object and images) will be seen in all?

Suggested method of use: Play the video and then ask the students to show from a diagram that the total number will be n where $360^\circ/\theta = n/m$ with n and m relatively prime integers. For example, $n = 4$ for $\theta = 90^\circ$ and $n = 6$ for $\theta = 60^\circ$, the two cases demonstrated in the video.

where we teach this: multiple reflections in Physics II
textbook reference: CJ E25.2; HRK Chap. 27

<u>Demo 22-10 "Disappearing Eye Dropper"</u>
A glass eye dropper full of air sits in a clear fluid. When the bulb is squeezed to suck liquid up the dropper, it vanishes because of an index match between the glass and liquid.

Suggested method of use: Before playing the video, ask the students to explain under what conditions you can see a transparent object sitting in a transparent fluid.

where we teach this: index matching in Physics II
textbook reference: CJ E26.7

Demo 22-15 “Laser Waterfall”
A laser beam is directed through a tank of water and into the nipple out of which the water flows. The laser beam is guided down the water jet into the catching tank below.

where we teach this: fiber optics in Physics II
textbook references: CJ p. 792; HRK Sec. 43-6

Demo 22-16 “Real Image Formation”
A lamp and screen are a fixed distance *d* apart. When a convex lens is placed in between them, sharp images are found for two different positions of the lens.

Suggested method of use: Play the video and then ask the students to prove that for a lens of focal length $f \ll d$, the two required positions are approximately a distance f away from the lamp or screen.

where we teach this: thin lens equation in Physics II lab
textbook references: CJ Sec. 26.8; HRK Sec. 44-3

Demo 22-20 “Fillable Air Lenses”
Hollow convex and concave lenses are filled either with air or water and their effect on a collimated beam of light are demonstrated both in air and underwater.

Suggested method of use: Play the video and ask the students to answer the question when the video pauses. (Some students will probably be fooled by the fact that an air-filled concave lens slightly focuses when in air, so you may wish to draw a ray diagram explaining that.)

where we teach this: lensmaker equation in Physics II
textbook reference: HRK Sec. 44-3

Demo 23-16 “Interference Filters”
Glass plates with magnesium fluoride coatings of three different thicknesses transmit blue, green, and red, and reflect yellow, magenta, and cyan, respectively, the three primary computer screen and complementary printer colors.

Suggested method of use: Play the video and ask the students to calculate the minimum thicknesses of the three coatings, given that $n = 1.38$ for magnesium fluoride.

where we teach this: thin-film interference in Physics II
textbook references: CJ Sec. 27.3 (also see P27.13); HRK Sec. 45-4

Demo 23-18 “Soap Film Interference”
In reflection, a soap film first produces pale bands of colors, then more saturated colors, and finally it appears black just before breaking.

Suggested method of use: Play the video and then ask the students the textbook question below.

where we teach this: thin-film interference in Physics II
textbook references: CJ Q27.6; HRK Q45.27

Demo 23-20 “Michelson Interferometer with White Light”
Colored fringes are produced near zero path difference. The effects of misaligning one mirror or of inserting a hot object into one arm are demonstrated.

Suggested method of use: Play the video and then ask the students to explain the various effects. Also bring in a Michelson and demonstrate the Airy pattern produced using a HeNe laser source.

where we teach this: Michelson interferometer in Physics II
textbook references: CJ Sec. 27.4; HRK Sec. 45-6

Demo 23-22 “Infrared in Spectrum”
A thermopile detector is scanned through the spectrum of a carbon arc lamp dispersed by a prism.

Suggested method of use: Play the video and ask the students to answer the question when it pauses.

where we teach this: blackbody spectrum in Physics II
textbook references: HRK Fig. 49.3; Stowe Chap. 26; Beiser Sec. 2.2

Demo 24-07 “Polarization by Scattering”
A light beam passes through a milky fluid. A polarizer placed at various positions is used to investigate the polarization of the scattered light.

Suggested method of use: Play the video and then ask the students to explain the observations.

where we teach this: polarization by scattering in Physics II
textbook references: CJ Fig. 24.26; HRK Sec. 48-6

Demo 24-15 “Quarter Wave Plate”
A polarizer, quarter wave plate, and mirror can be used to create an antireflection filter when positioned in the correct relative orders and orientations.

Suggested method of use: View the video and then ask the students why order matters.

where we teach this: double refraction in Physics II
textbook reference: HRK Secs. 48-4 & 48-5 (also see P48.22)

Demo 25-02 “Spectral Absorption by Sodium Vapor”
The top edges of a sodium flame either appear bright or dark in transmission depending on the brightness of the source illuminating it.

Suggested method of use: View the video and ask the students to explain under what conditions the flame will switch from appearing bright to dark.

where we teach this: atomic absorption and emission in Physics II
textbook references: CJ Sec. 30.2; HRK Sec. 51-1