REAL TIME AND SLOW MOTION VIDEOS

FOR PHYSICS INSTRUCTION

A CREATIVE PROJECT

SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

MASTER OF ARTS IN EDUCATION IN PHYSICS

BY

SCOTT A. WHITSITT

DR. JOEL BRYAN - ADVISOR

BALL STATE UNIVERSITY

MUNCIE, INDIANA

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This creative project consists entirely of a series of videos that have been published on a YouTube channel (https://www.youtube.com/channel/UCcED9MDwLBSvl5VFJYTtWyA). This document presents a compilation of the descriptions composed for each of the videos. The title of each video is followed by the description text and the URL for each video.

Charged PVC Pepper Attraction

In this video you see an electrically charged piece of PVC pipe being brought near a mixture of salt & pepper that has been sprinkled on the table. The pipe has been rubbed with rabbit fur to add electrons to it and give it an overall negative charge. The salt and pepper are generally neutral and are, therefore, attracted to the pipe. At approximately 6.25% of actual speed, you can easily see the grains jumping up toward the pipe. Look closely and you'll see some grains that look like they're "falling" off of the balloon. Viewing it at this speed disguises the fact that these grains are actually being repelled from the balloon after having acquired extra electrons from the balloon itself.

https://www.youtube.com/watch?v=JuI3qMXMvvI

Arcs From a Tesla Coil

This video simply shows the arc produced by a high-voltage Tesla coil held near a piece of metal. If the voltage is high enough to overcome the dielectric strength of air, electrons will jump from the coil to metal creating an arc.

https://www.youtube.com/watch?v=BbN597Dnpvs

Water Balloon Pop

This video shows a couple of different water-filled balloons being popped while held steady. It is interesting to note how the water largely retains the shape of the balloon for an instant immediately after being popped. The only places where the round shape is disturbed are where the

pin punctured the balloon and almost directly opposite that site where the shards of balloon are pulled together and, ultimately, away from the water.

https://www.youtube.com/watch?v=XccTm8gxRc4

Popping a Balloon

In this video you see a couple of different balloons being popped. We kind of recorded this just for fun but from a physics standpoint, you can see how the tension in the stretched balloon pulls the shards of rubber away from the place where the original tear/hole was made in it.

https://www.youtube.com/watch?v=rySDg7PEj50

Water Balloon Drop

This video presents a couple of different water balloons bursting as they hit the ground. Although a simple idea, a physical analysis of the forces involved is probably too complex for the description of a YouTube video. Let's call this one interesting but "just for fun."

https://www.youtube.com/watch?v=eR1QIbrRiA4

Flipping a Card From Under a Coin

In this demonstration of Newton's first law, a card is placed on the tip of a finger with a penny balanced on top. The instructor uses a finger on his other hand to flick the card forward (away from himself) while the penny remains balanced on his finger due to inertia.

https://www.youtube.com/watch?v=LzdWRwsRvpQ

Dropped Eggs

We did this video pretty much because we had eggs and a high-speed camera and we thought it would be fun. It was. We dropped both eggs side-by-side from the same height. The egg

on the left hits the countertop while the egg on the right hits a plastic sheet stretched across the sink. Results are as expected.

https://www.youtube.com/watch?v=s8Pxkcv1TfM

Tuning Fork Dipped In Water

This video presents two different tuning forks dipped into a beaker of water after being struck shown at 1/16th speed. Even at this speed, it is difficult to see the tines of the 512 Hz fork move but the energy transferred to the water by forced vibration is obvious. The tines of the 320 Hz fork, however, can be seen moving.

https://www.youtube.com/watch?v=gTuna0qbXE8

Arcs in a Jacobs Ladder

This video shows the arc across the arms of a Jacob's Ladder. The apparatus is simple, if not readily available. Two conducting rods or stiff wires are attached to the output of a high-voltage transformer—in this case the transformer steps up the voltage from 120 vac to 10,000 vac. The stepped up voltage creates a potential difference at the bottom of the ladder large enough to break down the dielectric strength of the air between the rods and a spark jumps. The spark heats the air turning it into conducting plasma and a steady arc is established. The arc heats the surrounding air and, since hot air rises, so does the arc—at least until the arms are far enough apart to extinguish the arc. In this slow-motion video, you can see that the arc appears to be jumping back and forth between the rods. This would make sense since the electricity in the arc is alternating current which changes direction 60 times per second.

https://www.youtube.com/watch?v=36hySKOfYvw

Dropped Slinky

When done in the classroom, this demonstration simply happens too fast to really see what's going on but slowing it down by a factor of eight is truly revealing. Here, a slinky toy is dangled from the instructor's hand. When the instructor releases the top of the slinky, the bottom of the toy does not fall immediately but seems to defy gravity by remaining stationary until the rest of the slinky has collapsed. As the slow-motion video shows, the slinky begins falling from the top and the collapse travels downward as a longitudinal or compression wave.

An explanation: Consider each coil of the slinky as a separate system and picture free-body diagrams of coils at the bottom, middle, and top of the slinky. The bottom coil of the slinky has two forces acting on it—gravity pulling down and the tension of the coil directly above it pulling up. Each of the middle coils have three forces acting on them—gravity and the tension in the coil directly below it pulling down and the tension in the coil just above it pulling up. Like the middle coils, the top coil also has gravity and the tension in the coil below it pulling down but it is the instructor's hand pulling up on it. Now, when the instructor releases the top coil, it begins to fall. As the top coil falls, the tension holding up the coil directly below it diminishes and that coil begins to fall. Likewise, as the second coil begins to fall, the tension holding the third lessens and that coil begins to fall. This process continues downward through the slinky until all of the upper coils have begun falling and the tension holding up the bottom coil begins to drop allowing the bottom of the slinky to fall.

The key here is to remember that 1) the slinky is not a rigid body and 2) after the top coil is released, the reduction in tension holding up each successive coil depends upon how quickly each coil is accelerated downward. Since each slinky coil has mass, the elimination of upward tension cannot happen instantaneously and there will be a time interval between when one coil begins to

fall and when the coil directly below it begins to fall. Add up the delays between all the coils beginning their fall and this phenomenon makes perfect sense.

https://www.youtube.com/watch?v=LyJcbTxHX_8

Water Balloon Drop on Terry's Head

This is another "just for fun" video of a water balloon popping. This time our colleague Terry volunteered (yes, he actually volunteered) to have a water balloon dropped on his head. When we finally saw the video, we were all a bit surprised at how the balloon deformed around Terry's head before finally bursting.

https://www.youtube.com/watch?v=k4rtVC37BLw

Charged Balloon Pepper Attraction

In this video you see an electrically charged balloon being brought near a mixture of salt & pepper that has been sprinkled on the table. The balloon has been rubbed with rabbit fur to add electrons to it and give it an overall negative charge. The salt and pepper are generally neutral and are, therefore, attracted to the balloon. At approximately 6.25% of actual speed, you can easily see the grains jumping up toward the balloon. Look close and you'll see some grains bounce off of the balloon only to be pulled right back to it. You'll also see some grains that look like they're "falling" off of the balloon. Viewing it at this speed disguises the fact that these grains are actually being repelled from the balloon after having acquired extra electrons from the balloon itself.

https://www.youtube.com/watch?v=WWZ1Q0jJekc

Vertical Launch with Horizontal Motion

This projectile motion demonstration (also called "vertical gun and car") presents the independence of vertical and horizontal components of motion quite nicely. A low-friction cart

with a projectile launcher rolls down the track and launches a ball vertically into the air. At full speed it is obvious that the ball lands right back in the cart but when slowed down, one can see the clearly parabolic path the ball takes from launch to landing.

https://www.youtube.com/watch?v=oOOildzSRfc

Egg Inertia Trick x 8

This is a more ambitious variation on the "egg trick" that you can view at the link below. In this version, a second layer of 4 eggs is stacked on top of the first layer. Observe how much more important a factor friction between the cardboard and the plastic rings becomes in this attempt. The results aren't quite what we hoped for but we still consider this one a success!

https://www.youtube.com/watch?v=4BnML-QCHLg

Egg Inertia Trick x 4

This video is a great demonstration of Newton's first law. Here, four glasses of water are placed on a counter or table, a piece of cardboard is placed on top of the glasses, and four eggs (held in place by plastic rings) are then placed on top of the cardboard and arranged to be directly above each one of the glasses. A broomstick is used to whack the card sideways, pushing it out from under the eggs quickly and the eggs all drop into their respective glasses due to inertia. When we slow the action down, it is interesting to observe how friction between the cardboard and the plastic rings affects the results. We also recorded a more ambitious version of the "egg trick" which you can view at the link below.

https://www.youtube.com/watch?v=1yPgFXD1iZI

Falling Chimney

The "falling chimney" demonstration offers an opportunity to discuss inertia, gravitational acceleration, and rotational motion all at the same time and is another one that happens way too fast to see what's really happening. The apparatus itself comprises two boards connected by a hinge, a stick to hold up one of the boards at an angle, a ball balanced on the tip of the inclined board and a cup attached to the inclined board just below where the ball is balanced. The stick is pulled away allowing the inclined board to fall. When the dust settles, the ball has fallen right into the cup. Slowing the action down shows that the ball falls straight down (compare its motion to the ring stand placed to the right of the ball). Observe that the end of the inclined board falls faster than the ball does--it has to for the trick to work. But wait a minute. Doesn't everything on earth accelerate downward at 9.8 m/s^2? Yes, it does. The end of the board accelerates faster than the ball does because it is the board's center of mass that is accelerated at 9.8 m/s^2.

Inertia Ball

In yet another demonstration of inertia, a small plastic plate is quickly pushed out from under a ball which then falls into the cup they were both sitting on.

https://www.youtube.com/watch?v=EhB9jIQuhEc

Leaky Cup Drop

Also known as the "leaky bucket" demonstration, this video is a demonstration of free fall and the concept of microgravity. The instructor holds a cup of water with holes poked through the sides of the cup near the bottom. As the instructor holds the cup, water flows out of the holes as students expect. When the instructor drops the cup, the situation changes.

https://www.youtube.com/watch?v=3mQ80OGFO5Y

Monkey Hunter 1

The "Monkey Hunter" demonstration (also known as "hunter and monkey" or "monkey and hunter" or "monkey and gun") is considered a real classic in the world of physics demonstrations. It's called this because of the (admittedly cruel-sounding) set-up for the demonstration: A hunter wants to shoot a monkey that is hanging from a branch high in a tree. The hunter knows, however, that the monkey will let go of the branch and drop to the ground at the exact instant that the bullet leaves the barrel of his rifle. In order to hit the monkey, should he aim his rifle directly at the monkey as it hangs in the tree or should he aim it at some point below the monkey. If he is to aim it below the monkey, how far?

In this series of three videos, no monkeys (nor Monkies) are harmed—not even stuffed ones; nor is a rifle used. This apparatus consists of a spring-loaded projectile launcher that fires a plastic ball toward a target. The target is a hollow red ball that is open at the bottom. (This opening makes version 3 of this series kind of interesting.) The launcher is aimed directly at the target as it hangs from an electromagnet that is turned off by the launcher just as the ball leaves the barrel.

In this version (version 1) of the video, the launcher is level with the target as it hangs there. The projectile is launched, the target falls, and the two balls intersect at about 2/3 of the way to the ground. In fact, an examination of each video shows that it doesn't matter what configuration exists, the projectile hits the target as long as it was aimed at the target prior to dropping (and the target isn't too far away).

https://www.youtube.com/watch?v=TjGgoufkoLI

Monkey Hunter 2

The "Monkey Hunter" demonstration (also known as "hunter and monkey" or "monkey and hunter" or "monkey and gun") is considered a real classic in the world of physics

demonstrations. It's called this because of the (admittedly cruel-sounding) set-up for the demonstration: A hunter wants to shoot a monkey that is hanging from a branch high in a tree. The hunter knows, however, that the monkey will let go of the branch and drop to the ground at the exact instant that the bullet leaves the barrel of his rifle. In order to hit the monkey, should he aim his rifle directly at the monkey as it hangs in the tree or should he aim it at some point below the monkey. If he is to aim it below the monkey, how far?

In this series of three videos, no monkeys (nor Monkies) are harmed—not even stuffed ones; nor is a rifle used. This apparatus consists of a spring-loaded projectile launcher that fires a plastic ball toward a target. The target is a hollow red ball that is open at the bottom. (This opening makes version 3 of this series kind of interesting.) The launcher is aimed directly at the target as it hangs from an electromagnet that is turned off by the launcher just as the ball leaves the barrel.

In this version (version 2) of the video, the launcher is at ground level and aimed at the hanging target. The projectile is launched, the target falls, and the two balls intersect at about a foot above the table. In fact, an examination of all three videos shows that it doesn't matter what configuration exists, the projectile hits the target as long as it was aimed at the target prior to dropping (and the target isn't too far away).

https://www.youtube.com/watch?v=fN3LvNgoNSE

Monkey Hunter 3

The "Monkey Hunter" demonstration (also known as "hunter and monkey" or "monkey and hunter" or "monkey and gun") is considered a real classic in the world of physics demonstrations. It's called this because of the (admittedly cruel-sounding) set-up for the demonstration: A hunter wants to shoot a monkey that is hanging from a branch high in a tree. The hunter knows, however, that the monkey will let go of the branch and drop to the ground at the

exact instant that the bullet leaves the barrel of his rifle. In order to hit the monkey, should he aim his rifle directly at the monkey as it hangs in the tree or should he aim it at some point below the monkey. If he is to aim it below the monkey, how far?

In this series of three videos, no monkeys (nor Monkies) are harmed—not even stuffed ones; nor is a rifle used. This apparatus consists of a spring-loaded projectile launcher that fires a plastic ball toward a target. The target is a hollow red ball that is open at the bottom. (This opening makes this version of this series kind of interesting as you'll read below.) The launcher is aimed directly at the target as it hangs from an electromagnet that is turned off by the launcher just as the ball leaves the barrel.

In this version (version 3) of the video, the launcher is at ground level and aimed at the hanging target. Since we could not change the speed of our projectile, we moved the launcher and the target closer together. The projectile is launched, the target falls, and the two balls intersect at about half way down the ringstand. The projectile seems to disappear as it meets the target but what actually happened is that it went inside the hole in the bottom of the target and was expelled a little further down. (We couldn't have done this if we'd tried to.) An examination of all three videos shows that it doesn't matter what configuration exists, the projectile hits the target as long as it was aimed at the target prior to dropping (and the target isn't too far away).
https://www.youtube.com/watch?v=UJKS36Fva7Q

LED Christmas Lights

This video shows two separate strings of LED Christmas lights bundled up. The bundle on the left is plugged into the wall and the bundle on the right is plugged into the other end of the first bundle so they are all wired in series. If you were to record these two bundles on your phone's camera—which typically records at about 30 frames per second (fps)—you might see the lights

flickering a bit. When we slow things down by a factor of eight (recording at 240 fps), we see more clearly that the lights are, indeed, blinking on and off. In this case we can actually see that the bundles blink alternately with one bundle on while the other bundle is off. The blinking is still pretty quick. Slowing things down to 1/16th of full speed (480 fps) makes the phenomenon easier to see and watching it at 3% of full speed (1000 fps) makes the blinking even more apparent.

Why are they blinking? LED, as you know, stands for Light Emitting Diode and diodes only allow electricity to flow in one direction. When electricity flows in the "forward" direction through an LED, it lights up. When electricity tries to flow in the "reverse" direction, it can't and the LED remains unlit. Since these LEDs are plugged into a 60 Hz AC power source, the electricity flow is changing direction 60 times each second. As a result, the LEDs are only lit for half of the cycle. In this example, the strings are plugged in so that the forward direction for each one is the opposite of the other and the first string is lit while the second is dark and vice versa.

You can confirm this explanation with this data: In the 240 fps recording, a complete cycle of the lights (on to off back to on) consistently takes 4 frames to occur. In the 480 fps recording, a cycle takes 8 frames. In the 1000 fps recording, a cycle takes between 16 and 17 frames (use 16.5 frames).

https://www.youtube.com/watch?v=jyvsckKkLxY

Simultaneous Drop

This demonstration is intended to show the independence of horizontal and vertical motion as well as the acceleration of a mass due to the force of gravity. The apparatus is designed to launch two identical projectiles at exactly the same time. One is dropped vertically and the other is launched horizontally. In the classroom, students are often advised to listen to the sound of the balls hitting the ground to determine which one lands first because it usually happens too fast to

see the result easily. If the instructor is lucky, the clicks of the projectiles hitting the floor will be virtually simultaneous. Achieving this result can, however, be difficult and this video gives you an idea of why this is. The apparatus used in this video is designed to be attached to a ringstand but, as you can see, ringstands weren't really designed to fire projectiles. Most of the time, though, the result achieved in the classroom is acceptable.

https://www.youtube.com/watch?v=uzaxTDx1KgE

Pen and Hoop Demonstration

In this demonstration of Newton's first law, a plastic bottle is placed on a table, an embroidery hoop is balanced on the open mouth of the bottle and (in this case) a marker pen is balanced on top of the hoop directly above the mouth of the bottle. When the hoop is snatched away, inertia causes the pen to remain in the same vertical position while gravity causes it to fall right into the bottle. The key to making this trick work is pulling the hoop away from the inside rather than pushing it away from the outside. Pulling the hoop from the inside causes the hoop to stretch side to side slightly, pulling the top edge down and away from the pen. With the hoop no longer in contact with the pen, the pen is free to fall straight down. In this video, the closeup of the pen/hoop interface shows the hoop's edge being pulled down and then, due to operator error, coming back up to hit the pen causing this attempt to fail.

https://www.youtube.com/watch?v=hO7qStk87ug

The following figures are images of some of the screens that appear on the YouTube channel where these videos are published.

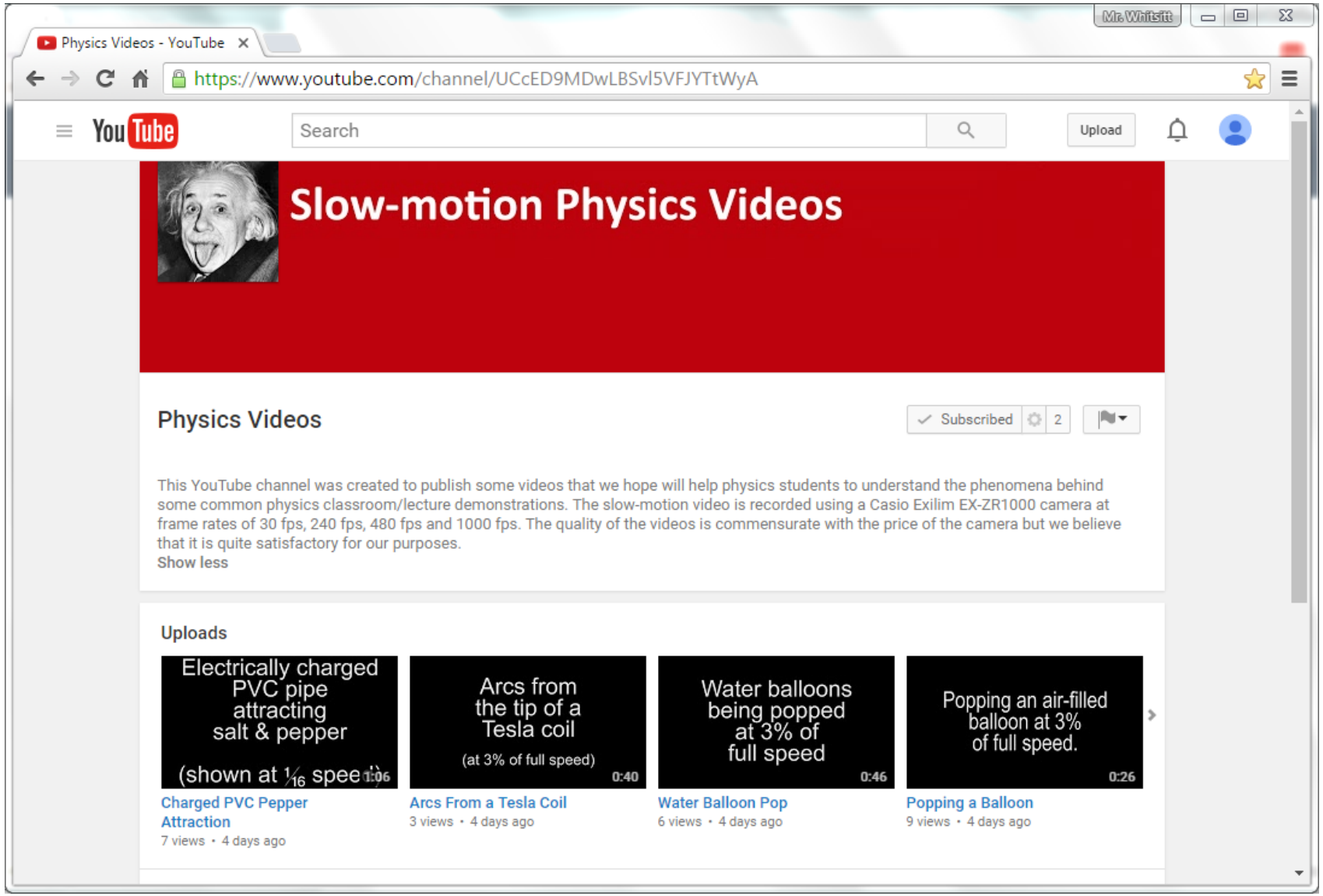

Figure 1: Home page of Physics Videos YouTube channel

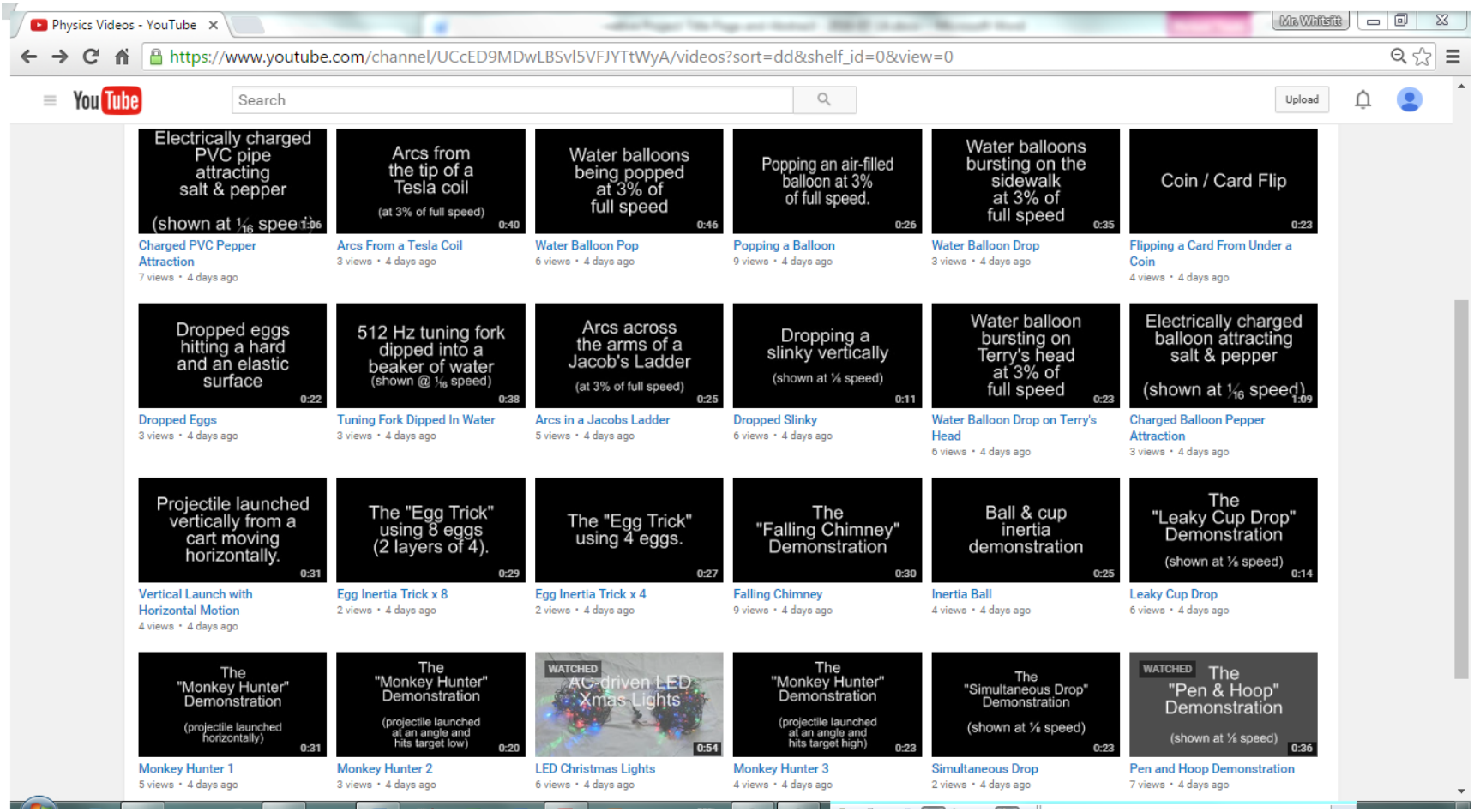

Figure 2: Contents of the YouTube channel

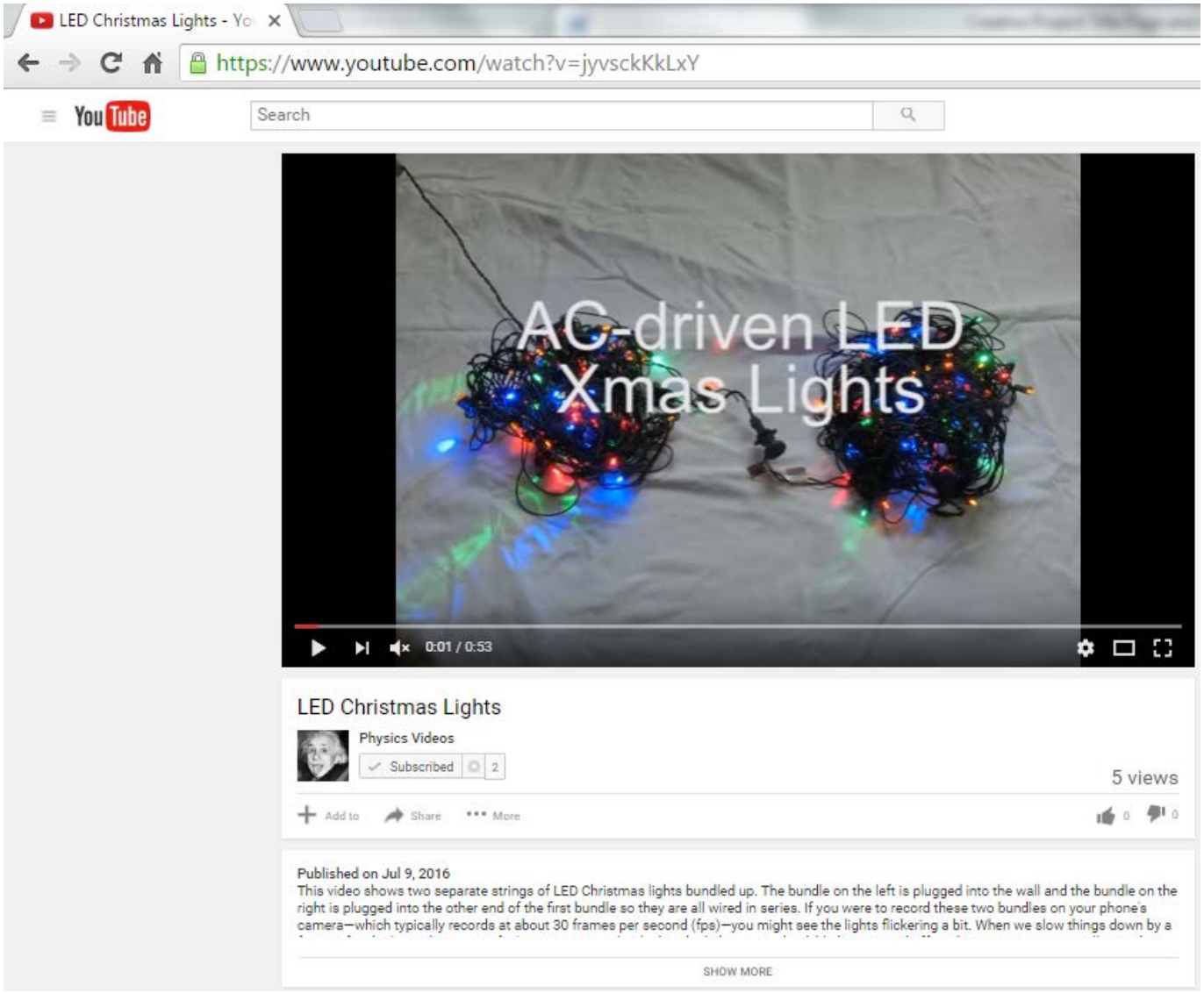

Figure 3: Example of an individual video page