LocoMotion

The Science & Circus Arts Show

Study Guide

This guide to Peter Davison's LocoMotion show tells the student BEFORE the performance what to look for and suggests things to do and think about AFTER the show — things related to objects in motion and what they tell us about the physical laws that govern their movements.

About the Artist

Peter Davison has performed for over 40 years. From a library book, at age twelve, he learned the basics of juggling. He began performing in public as a teen-age busker — a street entertainer — on the streets of Los Angeles. Over the years, helped by good teachers, he sharpened his juggling skills and added extensive training in dance and physical theater. The result: a well-rounded performing artist.

To championships in international juggling competitions, he has added recognition as a dancer, an award-winning choreographer, and co-artistic director of Boulder (Colorado) Ballet. He has conducted numerous workshops in performance skills, most notably for artists of Cirque du Soleil at the national circus schools of Canada and France. He has appeared on stages internationally and on numerous TV shows.

Peter has long been fascinated by — and long explored — the movement possibilities of objects. And of people. From that exploration came the idea for a show that examines the very nature of those movements. He calls it LocoMotion.

About the Show

LocoMotion entertains audiences with objects that spin, balance, fly, and float, and with dance and physical theater. The show mixes performing arts with insights into the physical science behind the artistry. It offers entertainment and education in one package. The title of the show has two meanings: Locomotion, in English, means "how we move from one place to another." And loco, in Spanish, means "crazy," so the show is also about "crazy motion!"

SOME BASIC DEFINITIONS:

SCIENCE

Science is how we learn about our world, and beyond, through experimentation and observation. Over centuries of such learning, science has become like a huge, ever-growing tree of knowledge. LocoMotion looks at just one branch of science called CLASSICAL MECHANICS, which is part of a larger branch of science called PHYSICS. Classical Mechanics is the science of objects in motion as described over three hundred years ago by Sir Isaac Newton and is the branch of science most useful to circus artists.

CIRCUS ARTS

Circus Arts are a category of the performing arts. Circus is an ancient Latin word meaning "circle" or "ring," and describes the shape of the stage upon which circus arts are traditionally performed, with the audience sitting all around. Although the first performance to be labeled a "circus" took place in England in 1768, many of the circus arts have been performed for thousands of years. These arts include juggling, balancing, acrobatics, aerial acts, clowning, and sometimes trained animal acts.

Let's look at the science behind the circus arts performed in the show:

JUGGLING

Force, acceleration, & projectile motion

Juggling is tossing and catching multiple objects in a skillful manner. This can be done with various objects including balls, scarves, rings, clubs, sticks, and even flaming torches. A juggling act is usually made up of different PATTERNS that prevent the objects from colliding in the air and create unique visual designs.

The science of juggling begins with FORCE, which is something that pushes or pulls objects to get them moving, or change how they are moving. Juggling uses APPLIED FORCE from the juggler's arms to toss objects into the air, and the FORCE OF GRAVITY, provided by our planet earth, to bring the objects back to the jugglers hands.

The applied forces and the force of gravity cause the juggled objects to ACCELERATE, which means to change speed or direction. For scientists, an object is accelerating if it is speeding up or slowing down, but many people use the term

DECELERATE in everyday conversation to specify slowing down.

A juggling ball thrown into the air is accelerated upwards by the applied force from the juggler's arm, but as soon as the juggler releases the ball, the force of gravity becomes the only force acting on the ball, accelerating it downwards. This acceleration from the force of gravity will slow the ball on its way up, cause it to peak for a split second, and then fall with increasing speed until it is caught.

Note that acceleration has nothing to do with how fast an object is moving, only that it is CHANGING speed. Acceleration is also caused by a CHANGE IN DIRECTION even if an object is traveling at a constant speed. (See CENTRIFUGAL & CENTRIPETAL FORCES on page 4.)

Objects being juggled are referred to by scientists as PROJECTILES, and juggling is a complex example of PROJECTILE MOTION. A projectile is an object that has been thrown or launched into the air (or into space!) and once the throwing force has stopped acting on the object, its motion is being changed only by the force of gravity (and, on earth, by a bit of air resistance). The PARABOLIC ARC that objects trace in the air as they are tossed from one hand to the other is a great example of projectile motion, in which we can see gravity curving the path of the object as it flies.

BALANCING
THE CENTER OF GRAVITY

The art of balancing has to do with what scientists call the CENTER OF GRAVITY, which is the place in an object around which the object's WEIGHT is evenly distributed. With a symmetrical object like a ball or yardstick, the center of gravity will be at the center. But sometimes the center of gravity will be located off-center, as with a tapered stick, larger on one end, or a person balanced on one leg, the other extended.


The great juggler Enrico Rastelli, late 1920's

Imagine a line from that point to the Earth's center, toward which gravity pulls the object. A support placed under the object precisely on that line will hold the object in balance. Thus for circus artists, the center of gravity becomes the BALANCE POINT.

Think of an UNSTABLE object, an object that cannot stand upright by itself, a yardstick, for example, balanced on a performer's finger. The performer must constantly move the point of support to keep it under the balance point. This means constant, quick hand movement in the direction the stick is tipping. A skilled circus artist's movements are small, almost invisible. This takes practice!

BALL & PLATE SPINNING

THE GYROSCOPIC EFFECT

For BALL SPINNING, the performer spins a ball in the air and catches it on a finger tip, where the ball continues to spin in a magical fashion. PLATE SPINNING was first performed in China over two thousand years ago, and involves spinning plates atop sharpened sticks.

When objects spin, their rotational INERTIA (see NEWTON'S LAWS, page 6) gives them stability and they don't want to change orientation, or tip. This stability from rotation is called the GYROSCOPIC EFFECT. This is also how a SPINNING TOP works. As rotation slows due mainly to FRICTION (a force that opposes rubbing or slipping of objects in contact) with whatever is supporting the spinning object, the object becomes less stable and will begin to tilt and eventually fall over. This tilting of the rotational axis of spinning objects is called PRECESSION.

PIERRE, THE FRENCH WAITER

CENTRIFUGAL & CENTRIPETAL FORCES

Circus artists often play different characters. In one segment of LocoMotion, Peter plays a French waiter named Pierre. Pierre places three glasses on a tray, adds water to each glass, then raises the tray to nearly vertical while turning rapidly, without dropping the tray and glasses, or spilling the water. Then he pours the water into a bucket and dances, swinging the bucket in circles without spilling the water. Pierre uses CENTRIFUGAL and CENTRIPETAL forces to accomplish these feats.

CENTRIFUGAL (derived from Latin, meaning "center fleeing") FORCE is the tendency for objects moving quickly in a circle to want to fly away from the center of that circle. It should be noted that centrifugal force

is NOT A TRUE FORCE, but an example of INERTIA (the tendency of moving objects to continue moving in a linear direction) applied to circular motion. But centrifugal force is a useful term to describe this effect.

CENTRIPETAL (from Latin, "center seeking") FORCE is a TRUE FORCE that pushes or pulls objects toward the center of a circular path.

Pierre's hand provides centripetal force to the tray and its contents to counter the centrifugal force impelling them to fly away. Thus the objects remain apparently "stuck" to the hand.

Note that although the objects are moving at a constant speed, they are ACCELERATING because they are continually changing direction.

UNICYCLE RIDING

LOCOMOTION

The English word LOCOMOTION means "how we move from one place to another." Locomotion includes activities like walking and running, and using machines to move around. In the circus such a machine is a unicycle. The science of unicycle riding is similar to that of any wheel-powered machine, such as a bicycle, car, or train. But the unicycle is difficult to ride because it is extremely unstable!

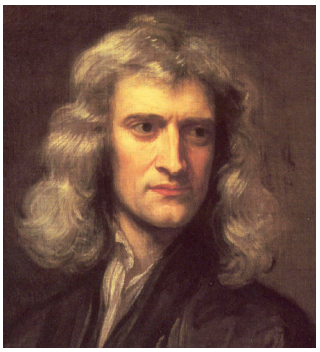
All forms of locomotion are explained by NEWTON'S THIRD LAW (see NEWTON'S LAWS, page 6), which states that for every action, there is an equal and opposite reaction. So, for locomotion, *we must apply a force opposite to the direction we wish to go*. For example, when we pedal a unicycle forward, the bit of wheel touching the floor will push backwards against the floor. The floor will REACT by pushing forward against the wheel with equal force, impelling the unicycle forward. And visa versa when pedaling backwards.

This reaction from the floor is also made possible by the forces of GRAVITY and FRICTION which prevent the wheel from spinning in place and enable it to push forwards or backwards against the floor.

The force provided by the unicyclist's legs being applied to the wheel through the pedals is called a TORQUE FORCE. Torque is a type of force that causes an object to rotate.

BALANCING ON THE UNICYCLE is done by moving the wheel under the rider's center of gravity, like a feather balancer moves their hand under a feather to maintain its balance. These balancing movements are accomplished by precisely controlling the speed of the wheel in the forward/backward direction, and twisting of the hips to turn the wheel. A unicyclist must keep the wheel moving almost constantly to maintain balance!

NEWTON'S LAWS OF MOTION



Sir Isaac Newton was an English scientist who lived from 1643 to 1727. Legend has it that an apple falling from a tree and bonking him on the head caused Sir Isaac to start thinking about gravity. Based on his own account of the story, it is more likely that he merely *watched* the apple fall. Newton's three LAWS OF MOTION, published in 1687, reveal a lot about the science of circus arts.

FIRST LAW - THE LAW OF INERTIA. *Objects will remain at rest or moving at a constant speed and direction, unless acted upon by an unbalanced force.*

Examples of INERTIA include CENTRIFUGAL FORCE, where an object would fly away in a straight line but is forced to move in a circle instead, creating the effect of the object being pushed away from the center of the circle, and the GYROSCOPIC EFFECT where we see that a rapidly spinning object maintains its orientation.

SECOND LAW – *Acceleration of an object depends on its mass (the amount of matter something is made of) and the amount of force applied to it.*

For example, if I push harder (more force) on the unicycle pedals, I will accelerate faster. If I have someone sitting on my shoulders while I ride, I have more mass to accelerate so I will have to push harder on the pedals to achieve the same acceleration.

THIRD LAW - *For every action there is an equal and opposite reaction.*

In addition to the example of unicycling on page 5, examples of Newton's Third Law include WALKING (feet pushing backwards against the ground to walk forward), a BOAT (propeller pushes water backward and the reaction pushes boat forward), or an INFLATED BALLOON that flies around the room when released (air is squeezed out of the opening, and the balloon is propelled in the opposite direction).

PRACTICING

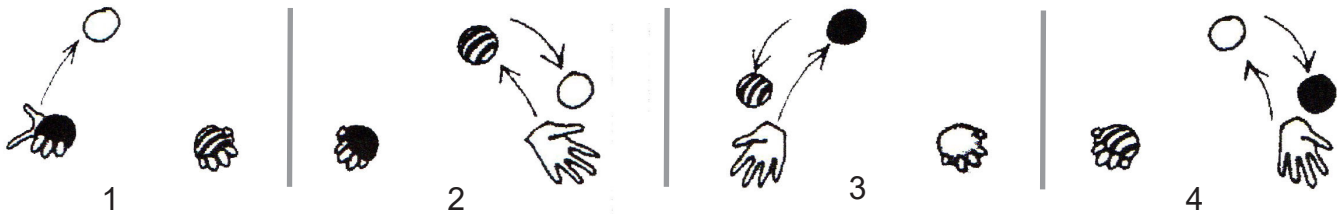
It's good to know about the science of circus arts when learning how to do them. But practice is still required even though we may *understand* what we are trying to do, because we have to train our mind and muscles to accomplish the precise actions needed. Often, these actions must occur faster than we can think about them, and practicing is how we can gradually acquire the faster-than-thought reflexes to accomplish them. Some tricks can be learned in one session, such as some of the THINGS TO DO explained below. Other tricks take years to learn.

TIPS FOR PRACTICING: *Shorter practice sessions* spread over several days, with sleep in between, will be more effective than one long practice session. And it always helps to have a qualified teacher as a guide!

THINGS TO DO

THREE BALL JUGGLING

The basic juggling pattern with three objects is called the CASCADE. This is a symmetrical pattern in which each object thrown follows a parabolic arc to the other hand. We learn the Cascade pattern by practicing first with one ball thrown from hand to hand, then two balls, then three, with consistency acquired at each of these stages. Here is an illustration of the pattern:



You can view a JUGGLING TUTORIAL VIDEO here: http://poetofmotion.com/tutorials. On this same web page you can find a tutorial on SCARF JUGGLING, the easiest way to learn, since scarves fall slower due to air resistance.

Finding the Center of Gravity

A fun way to find the center of gravity of a stick is to hold the stick horizontally near its ends on the edge of each hand, then slowly move your hands together. You will notice the weight of the stick shifting from one hand to the other several times as your hands move closer, until your hands meet at the center of gravity,

or balance point. Note that if you do this with a broom or hockey stick, which has more weight on one end, the center of gravity will be off-center.

Feather Balancing

Peacock feathers are excellent for balancing, since their large surface area and low mass enable a force called AIR RESISTANCE (aka DRAG) to slow their fall and allow more reaction time to correct the balance. Supporting the feather vertically on an open hand will place the center of gravity more or less straight above the support point (hand). With many quick reactions you can move your hand to keep the feather balanced.

More advanced techniques include balancing the feather on one finger, nose, chin, forehead, shoulder, or foot. You can also try hopping the feather from hand to hand while balancing. All of these tricks require practice to increase the speed of your reactions!

TIP - Be sure to look at the TOP of the feather (or any object) while balancing, because the top moves further than the bottom as the object tips. This gives a clearer visual cue for restoring the balance.

Coin & Hoop Spinning

You can hold a COIN upright on a table, with one finger on top, and with a careful flick of another finger get the coin spinning on its edge. This is an example of the gyroscopic effect. While the coin is rapidly spinning, it will remain upright.

A fun trick to try in a large space is to spin multiple HOOPS (such as hula hoops) in a similar fashion to the coin spin, on edge, with a flick of the wrist. It takes some practice to make the hoop spin in one spot. One or more performers can try to keep several hoops spinning by running around and re-spinning the hoops before they settle to the floor. MINI VERSION: keep multiple coins spinning on a table!

The Clown Stumble

This is a classic clown technique. You walk along and then get one foot stuck behind the ankle of the other leg, causing a stumble. This technique illustrates the LAW OF INERTIA since your upper body continues moving after your foot gets stuck. Of course you have to free the stuck foot in time to catch yourself before you fall!

Beach Ball Toss & Pirouette

A lightweight, slower-falling beach ball (AIR RESISTANCE!) is good to use for this trick: toss the ball straight up, pirouette (spin yourself around on one foot), then catch the ball. Toss and catch using two hands. TIP - It is helpful to separate the trick into three distinct actions: throw the ball accurately, then pirouette, then catch. Although done in rapid succession, keeping these actions distinct will help prevent wild throws or catches. It is also helpful to "spot" the ball in the air so you have a good idea of where and when it is going to come down.

PIROUETTE TIPS - Stand with your feet about shoulder width, push back with one foot to spin your body around while balanced on the ball of the other foot. The spin should be fast, and you will stop by putting the raised foot back on the ground. Try to hold your body straight like a pencil while turning.

Plate Trick

You can do a version of Pierre's tray trick with unbreakable plates. A simple way to make UNBREAKABLE PRACTICE PLATES is to glue 5 or 6 paper plates together to make a heavier, yet unbreakable plate that works well for circus tricks. If you hold a plate on your hand and rotate your body quickly (see PADDLE TURN on page 10) you can raise your forearm to a vertical position and the plate will remain on your hand, held in place by the balance of centrifugal force "pushing" the plate away from your axis of rotation, and centripetal force from your hand "pushing" the plate back toward center. TIP - Be sure the plate is FACING YOU as you raise your arm while spinning.

Advanced versions of the plate trick include spinning with a plate in each hand, spinning with another prop on the plate (objects with a LOW CENTER OF GRAVITY work best), and transferring the plate from one hand to another while spinning.

(You can see the above plate trick, and a couple of others, demonstrated online at http://poetofmotion.com/tutorials)

Paddle Turn

This is a common step in ballet and European folk dances, and is a good technique for spinning your body continuously while staying in one spot. You stand on the ball of one foot which provides a pivot point. The other foot pushes you around over and over, like a fast-moving canoe paddle. Use two paddle-pushes for each full rotation of your body.

Dizziness

After spinning several times in one direction the fluid in your inner ear begins to rotate along with you. When you stop spinning, dizziness occurs because the fluid continues to move for awhile (INERTIA!), telling your motion-sensing nerves in your inner ear that you are still moving. Some tactics to help relieve dizziness quickly are spinning twice in the opposite direction, or stomping on both feet three times.

Interesting Points to Ponder

- Mass and weight are different concepts. Mass is how much matter an object is made of. Weight is the effect of gravity on a mass.
- All objects exert a force of gravity, and that force is relative to the object's mass. When two objects interact, gravity pulls them together, but the object with less mass will move more.
- The word "centrifugal" is often mispronounced "centrifical," and "centrifugal force" is not in itself an actual force. It is an effect of inertia.
- Acceleration is defined as a change in velocity. Velocity is speed in a particular direction. So a change in either speed or direction is an acceleration.
- A tossed object is accelerating toward the earth both on the way up and way down.
- Objects of different mass, when dropped from the same height, will land on the ground at the same time. Although gravity has a stronger pull on the more massive object, making it feel heavier, its greater mass requires greater force to accelerate, as explained by Newton's second law. It so happens that gravity's stronger pull is exactly cancelled out by the resistance to acceleration in the more massive object. Thus objects of different mass fall with the same acceleration (barring any effects from air resistance).
- Newton's apple tree still lives at Woolsthorpe Manor in Lincolnshire County, England. It is about 400 years old.

RESOURCES

PETER'S WEBSITE:

https://poetofmotion.com

ONLINE VIDEO TUTORIALS:

https://poetofmotion.com/tutorials

JUGGLING & OTHER CIRCUS EQUIPMENT:
https://dube.com
https://www.renegadejuggling.com

UNICYCLES:

https://www.unicycle.com

ONLINE PHYSICS TEACHING TOOLS:

https://physicsclassroom.com

SOME GOOD BOOKS:

"The Complete Juggler" by Dave Finnigan
"Be A Clown" by Turk Pipkin
"Performing Basic Circus Skills" by Jack Wiley
"The Physical Comedy Handbook" by Davis Robinson