<u>Circular Motion</u>

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<u>Main concepts:</u>

1) Newton's First law of motion says: Any object will tend to remain at rest or at constant velocity unless acted on by a force. This means that a moving object will always go in a straight line at constant speed, unless a force pushes it to speed up, or slow down, or change direction.
2) When an object moves in a circle, there must be a force pointing toward the center of the circle to hold it on this circular path. This force is called the Centripidal Force.

Sir Isaac Newton lived (1642 – 1727)

<u>What to do</u>

Today we are going to talk about circular motion. (this means moving in a circle).
Twirl the **racquet ball on a string** around in a circle.
Circular motion is all around us. Ask the students to think of some examples of circular motion: A ball on a string. Planets orbiting the sun. a car driving around a curve, a swing, a ferris wheel, a roller coaster that goes upside down in a loop.
Show the Hot Wheels race track. When the car goes around the loop, why does it not fall down ? That's what we are going to find out today.

<u>Motion in a straight line</u>

Ask the children. If I throw a ball will it go on forever, or does it come to a stop ? Demonstrate by **rolling a ball** across the floor slowly so that it comes to a stop.
The ancient Greeks thought that solid objects tend toward being still. So if you roll a ball, it would slow down and stop. Today we know this is not true. The object tends to move in a straight line at constant velocity. It only slows down because of friction.
In physics we want to uncover the simple underlying physical laws. The real world has lots of complicated effects so we have to remove those complicated effects before we can reveal the simple laws that govern motion. In this case we need to remove the **friction.**

Explain what friction is (rubbing). Ask the children, how can we remove friction (air hockey table).
Show **Air Track:** A car on the track moves in a straight line and does not slow down because it is frictionless. Introduce Newton's 3 Laws of motion. Show picture of Sir Issac Newton.
Newton's First Law says: An object will tend to remain at rest or at constant velocity unless acted on by a force. This means that a moving object will always go in a straight line at constant speed, unless a force pushes it to speed up, or slow down, or change direction.
Speed is the distance moved in a specific amount of time (like miles/hour or meters/second).
Velocity includes speed and direction both. For example, if a ball bounces off a wall, its speed may not change, but its velocity did change, because its direction changed.
What is a **Force** ? Throw a rope to the students, let them grab hold, and tug a little bit so they can feel the force.

Put the small **Teddy bear** on one of the air cars and give it a push. The bear and the car travel at constant velocity. If we suddenly stop the car, the bear still goes forward. This shows that once an object starts moving, it wants to continue in the same direction. Relate this to the example where your mother is driving you to school and she steps on the brakes hard. You seem to go flying forward. But your are only moving relative to the car. In reality you are just continuing to move in a straight line at the same speed as you were, and it is the car that is stopping out from underneath you !

Circular Motion

Return to the spinning **racquet ball on a string.** Ask the children: what direction is the ball going when it is at the top of the circle ? Demonstrate by letting go of the string when the ball is at the top, and it flies off to the left. What direction does it go if I let go at the bottom (it flies off to the right). What direction does it go if I let go at the right side (it flies straight up). Draw a circle with arrows on the board to make sure this is clear.

Ask the children: what force is required to keep this ball moving in a circle ? We've seen that if I let go of the string, the ball will move in a straight line. So what is providing the force to keep the ball curving on a circle ? Answer: The string provides the force.

What direction is the force: Answer: toward the center of the circle. Put an **Arrow on the string** pointing toward the center. Let's prove to ourselves that the force is toward the center.

Put blue masking tape on the floor in a large Arc (tape down one end of a ~15 foot rope to act as a radius). Have the children get down on hands and knees and roll a ball along the tape line. Directions, roll it in a straight line, and then make small corrections to keep it on the curve. As you do it, try to answer to this question. What direction do you have to push the ball to keep it on the circle ?? Then ask the students what they observed. Guide the students to realize that the ball tends to go off the circle in a straight line, so we need to push the ball toward the inside of the circle to keep it on the curve. Explain that an arc (or curve) is just a section of a circle. So what we find out for the arc will also be true for the circle.

??? Return to the racquet ball on a string. Swing the racquet ball in a circle (a circle in a vertical plane) and ask the students: "what will happen if I cut the string ?". Let the children guess what will happen. Let go of the string and the ball should fly off in a straight line. Repeat a few times.
This shows that objects really do want to move in a straight line.

Optional: Force is along the string. Actually, think about it, can the string put any force on the ball in another direction (such as perpendicular to the string) ? No the string can only provide a force along the direction of its length.

Now think about when you are in the car and your mom drives around a corner. Going around the corner is just a curve, or a section of a circle, right ? Think about it, do you get pulled toward the inside or toward the outside of the circle ?

Show drawing of top view of a car going around a curve. The students should conclude that you feel a force toward the outside of the circle.

Go back over to the blue tape on the floor. Presenter gets on the tricycle and holds the car door. Ask which direction do you feel a force ? Everyone should agree that you feel a force toward the out side of the circle. But we said that in order for the car to drive around a circle (or an arc), there must be a force toward the center of the circle. So why do you get pulled toward the outside of the circle ?

Newton's third Law says: For every Force there is an equal and opposite force.
The tires on the car provide the force toward the center of the circle (keeps the car on the arc rather than going straight). But your body also wants to continue to go straight, just like the teddy bear on the air track. So the car door and your seat belt must exerting a force on your body to keep you turning with the car.

Introduce the words: Centripetal and Centrifugal.

Centripetal means to be pulled toward the center.
Centrifugal means to be pushed away from the center.

Now consider a **planet in orbit around the sun**. Show plastic Earth orbiting around a plastic Sun. Ask the children. What is holding the Earth in orbit around the Sun ? There must be some force toward the center. Answer: The gravity of the Sun, provides a force exactly in the direction from the Earth toward the sun.
Show the video of a cannon shooting a cannon ball around the Earth. This shows that the motion of a projectile is actually the same as the motion of a planet orbiting the sun. They are both falling toward the center because of a centripetal force.

Return to the Hot wheels loopty loop car set. Ask the children to point out the direction of the centripetal force, and of the centrifugal force.

<u>Twirling Bucket of Water</u>
You need a metal bucket with a solid handle and gloves, and practice ahead of time.
Caution: Explain to the children that this plane where I will spin is dangerous. Do not get up out of your seats. Start with your main bucket empty, and pour some water from a spare bucket into your main metal bucket. How much water should I add ? This much ? more ? more? You guys really want me to get wet don't you. Spin the bucket and show that the water does not come out. Ask the children to explain how this can happen.

Now stack up blocks on the flat board. Start with one block and demonstrate by spinning. Then two, then add more. How many can I you do without crashing ?

Optional: Put a **Sticky man on the Globe** and spin the globe.
Calculate the speed that we are traveling around a circle due to the rotation of the Earth.
Speed = πD/ time = 3.14 x 8000 miles / 24 hours ~ 1000 miles per hour.
Question: if we are going around a circle at 1000 mph, why do we not fly off into space ?
The answer is that the gravity holding us down on the Earth is much stronger than the centrifugal force that pulls us away from the Earth.

Equipment needed

Racquet ball on a string

Optional: use a Merry-go-Round in a playground

Top for example.
Ball to roll across the floor.
Picture of Sir Issac Newton
Air track + V-Blocks + 2 cars + Shop Vac.
Small Teddy bear.
Ruler or pointer to stop the air car.
Arrow on the string
Blue tape on floor
Words: Centripidal, Centrifigal Force.
Rope to show a Force
Picture of car going around a curve.
Tricycle and car door.
Extra clamps
Plastic Earth & Sun.

Hot wheels car set & 2 cars
Extra D-size batteries
Bucket of water for spinning
Blocks and flat board for spinning

Cannon to shoot a projectile
DVD: NOVA – Newton's Dark Secrets

Rubber ball for the Sun
Dry Erase board and stand.
Globe, Stand, and sticky man.

<u>Circular Motion</u> - <u>Summary</u>

Spin Racquet Ball on a String
Examples of Circular Motion (Bicycle wheel, Top, Ferris Wheel, Roller Coaster)
Hot wheels car. Why does it not fall down ?

<u>Motion in a straight line</u>
Roll a ball
Ancient Greeks believed
Friction
Air track
Newton's First Law
Explain: Force, Speed, Velocity
Stop the car and Teddy bear continues forward.

<u>Circular Motion</u>
Racquet ball on a string
Explain Force is toward the center
Tape on floor – Roll balls

Racquet ball on a string
Experiment proved that we need a Force toward the center
Let go of the string and Racquet ball flies off in a straight line.
String provides the force

<u>Car going around a curve.</u>
Tricycle and car door on the blue tape road.

Top view of car going around a curve.
Force away from center
Words: Centripetal
Centrifigal;

Plastic Earth & Sun.
Video of the cannon ball orbiting the Earth.

Hot wheels car set.
Twirl the bucket of water
Twirl the blocks on a flat board

Optional: Sticky man on the Globe

Definitions:

Centripetal \Cen*trip"e*tal\, a. [L. centrum center + petere to move toward.]
1. Tending, or causing, to approach the center.

2. (Bot.)
   (a) Expanding first at the base of the inflorescence, and proceeding in order towards the summit.
   (b) Having the radicle turned toward the axis of the fruit, as some embryos.

3. Progressing by changes from the exterior of a thing toward its center; as, the centripetal calcification of a bone. --R. Owen.

Centripetal force (Mech.), a force whose direction is towards a center, as in case of a planet revolving round the sun, the center of the system, See Centrifugal force, under Centrifugal.

Centripetal impression (Physiol.), an impression (sensory) transmitted by an afferent nerve from the exterior of the body inwards, to the central organ.

Centrifugal \Cen*trif"u*gal\, a. [L. centrum center + fugere to flee.]
1. Tending, or causing, to recede from the center.

2. (Bot.)
   (a) Expanding first at the summit, and later at the base, as a flower cluster.
   (b) Having the radicle turned toward the sides of the fruit, as some embryos.

Centrifugal force (Mech.), a force whose direction is from a center.

Note: When a body moves in a circle with uniform velocity, a force must act on the body to keep it in the circle without change of velocity. The direction of this force is towards the center of the circle. If this force is applied by means of a string to the body, the string will be in a state of tension. To a person holding the other end of the string, this tension will appear to be directed toward the body as if the body had a tendency to move away from the center of the circle which it is describing. Hence this latter force is often called centrifugal force. The force which really acts on the body being directed towards the center of the circle is called centripetal force, and in some popular treatises the centripetal and centrifugal forces are described as opposing and balancing each other. But they are merely the different aspects of the same stress. --Clerk Maxwell.

Centrifugal impression (Physiol.), an impression (motor) sent from a nerve center outwards to a muscle or muscles by which motion is produced.

Centrifugal pump, a machine in which water or other fluid is lifted and discharged through a pipe by the energy imparted by a wheel or blades revolving in a fixed case. Some of the largest and most powerful pumps are of this kind.

The Physics of the Ancient Greeks

The Motions of Objects

One of Aristotle's interests was the motion of objects:

- Why does a rock fall while smoke rises?
- Why does water flow downward while flames dance into the air?
- Why do the planets move across the sky?

He explained this by saying that all matter is composed of five elements:

- Fire
- Earth
- Air
- Water
- Aether (divine substance of the heavens)

The four elements of this world interchange and relate to each other, while Aether was an entirely different type of substance. These worldly elements each had natural realms. For example, we exist where the Earth realm (the ground beneath our feet) meets the Air realm (the air all around us and up as high as we can see).

The natural state of objects, to Aristotle, was at rest, in a location that was in balance with the elements of which they were composed. The motion of objects, therefore, was an attempt by the object to reach its natural state. A rock falls because the Earth realm is down. Water flows downward because its natural realm is beneath the Earth realm. Smoke rises because it is comprised of both Air and Fire, thus it tries to reach the high Fire realm, which is also why flames extend upward.

There was no attempt by Aristotle to mathematically describe the reality that he observed. Though he formalized Logic, he considered mathematics and the natural world to be fundamentally unrelated. Mathematics was, in his view, concerned with unchanging objects that lacked reality, while his natural philosophy focused upon changing objects with a reality of their own.