Zap! (Electric Discharge)

You are shuffling along a carpet and reach out to touch the doorknob and – zap! – a sudden electric discharge gives you a mild shock. The friction between your feet and the carpet has produced a large build-up of negative electric charge on your finger. This produces an electric potential difference, or voltage, between your finger and the doorknob. If the electric potential difference is large enough, a sudden flow of current, called an electric discharge, will occur. An electric voltage can also be produced by the rotation of a magnet in the presence of an electrical circuit. This is the principle behind a generator. Rapidly spinning, highly magnetic neutron stars can act as generators and produce electric voltages in excess of a trillion volts.

Violent electric discharges are responsible for some of the most spectacular displays of sudden energy release on Earth and in space.

Q: Where can electric discharges occur?
A: Here, there, and everywhere that electric voltages are large enough. For example, in an arc welder, a storm cloud, and around a rapidly spinning neutron star.

Activity 1 - Leyden jars and static electricity

Core concept: positive and negative electric charges can be separated to build up a high voltage, and this voltage can be discharged when the conditions are right. This activity will use Leyden jars to safely explore charge separation and electrical discharge.

Exhibit connections: Electric Discharge panels 1 - arc welder and 2 - lightning

Materials: balloon, Leyden jar, pvc pipe, square of animal fur, image of lightning

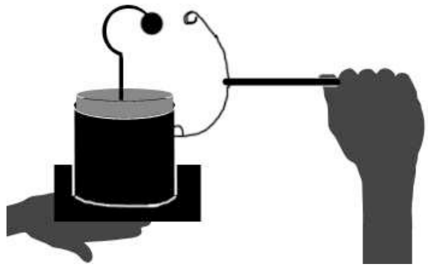
Background:
Electricity is a fascinating subject for many people, though it can sometimes be dangerous to experiment with. These experiments provide a safe environment to closely observe electric discharge. When you shuffle your feet on the carpet or wear a wool sweater, you're temporarily creating an excess distribution of electrons on your body. When the charge has a convenient place to go with fewer electrons, like a metal doorknob, it leaps at the opportunity, and zap! The static electricity "discharges," or jumps to the new place, creating a spark. The number of positive and negative charges are equalized again!

The Leyden jar is a device made to safely capture this static electricity, and then watch the energy being discharged (without a painful shock!) A Leyden jar will shock you if you discharge it onto your fingers, so be careful! When you rub the animal fur over the plastic rod, you create a temporary separation of charges, which can be transferred to the stem of the Leyden jar. The base of the Leyden jar acquires a positive charge. When you use the discharge rod to create a convenient path for the electrons to travel quickly across, they quickly jump across the gap and produce a spark.

Misconception Alert:
Understanding electricity concepts can be particularly challenging for adults and children alike. Many people confuse ideas and terms related to voltage, current, and electrical charge. The exhibit images focus on electrical conditions (here, there, and everywhere) that produce high *voltage* that can lead to sudden discharges of electrical energy across space. These activities can help visitors observe, experiment with, and describe phenomena related to voltage, electrical potential difference, and electrical discharge.

Suggestions for introducing the activity:
Ask visitors if they have ever gotten a shock from touching a doorknob or other metal object? Blow up a balloon and rub it against your hair (or a visitor with long straight hair). Now try pulling the balloon away from the hair. What happens? By rubbing the balloon on your hair, you've charged it by picking up negative electrons from your hair. Your hair now has a positive charge, and the balloon has a negative charge. Objects with different charges are attracted to each other, strands of your hair will stick to the balloon! On the other hand, objects with the same charge repel one another, so each strand of hair tries to get far away for the other strands - usually by standing straight up!

Procedure:
To use the Leyden jar, first generate static electricity by quickly rubbing the fur over the PVC pipe. Now run the pvc pipe along the stem of the Leyden jar. The Leyden jar will collect the static electricity, and store it until it can escape. Repeat this process at least 3 times, building up negative charge on the stem of the Leyden jar. Then, touch one end of the discharge wand to the outside of the jar, and slowly bring the other end towards the top ball joint, until, zap! A spark is produced! The more static electricity stored, the higher the electric potential, or voltage, and the longer, brighter and louder the spark will be.



Discussion/Questions for visitors to consider
Ask visitors what they think the differences are between the small spark made by the Leyden jar and a lightning strike. This tiny spark is really the same as lightning, only on a much smaller scale. Static electric charge builds up in clouds when water and ice particles collide. The negative charge in the cloud is attracted to positively charged objects on the ground. The charge from the cloud is released in the form of lightning, with a much bigger zap! Ask visitors to observe the image of lightning. Do they notice the branches or forks in the lightning? These branches are actually multiple strikes. Can visitors hear a sound when the spark discharges from the Leyden jar? Is there an equivalent sound when lightning strikes? You bet, it's called thunder!

Activity 2 – Plasma Ball

Core concept: Electricity flows from high voltage to low voltage via the most convenient path.

Exhibit connections: Electric discharge panel 1 - arc welder

Materials: Plasma ball, image of sparks produced by welding

Background:
A plasma ball is a glass globe filled with noble gases, with a high-voltage electrode at its center. Electricity excites the atoms of noble gas (see the glowing gas activity for much more on this reaction) making the flow of electricity visible. The electricity inside the globe flows from the center out towards the air. When your hand comes near, the spark flows in that direction, since you're a more convenient path to the ground (the voltage between the electrode and your hand will be higher than between the electrode and the air).

Suggestions for introducing the activity:
Show visitors the plasma ball and explain a bit about how it works. Ask visitors if anyone has seen one of these devices before, and in what setting. They are mesmerizing decorations!

Procedure:
Encourage visitors to experiment with the plasma ball. Ask them if they have any ideas about what is going on. Placing a hand or a finger near the glass creates a much more attractive place for the energy to flow, so it immediately travels in that direction. What happens when they hover a hand over the top of the ball but don’t touch it? The plasma in the ball can still somehow “sense” you are there! Try touching the ball with one finger. Try 2 fingers! Ask 2 visitors to touch the ball at the same time. What happens?

Discussion/Questions for visitors to consider:
Ask visitors to look at the image of the sparks produced by arc welding. How are these similar/different to the sparks produced in the plasma ball?

Activity 3 – Hand Held Generator

Core concept: When a coil of wire is spun around a magnet, the magnet produces an electric current in the wire. This activity will use a hand generator to explore how rotating magnets can generate an electric potential, or voltage, which produces a current in a wire.

Exhibit connections: Electricity panel 3 - spinning stars

Materials: hand-crank electricity generator, image of neutron star, image of Crab Nebula

Background:
A hand crank generator is an excellent smaller version of what creates much of the electricity that powers our lives. Wind turbines, steam engines, and waterwheels all operate on very similar principles. These generators convert some kind of mechanical energy, such as hot steam rising or water falling, into electrical energy. This small hand generator is made of a few coils of wire around a magnet. When you turn the crank, the wire coils spin around the magnet, which produces an electric current in the wire! This electric current can be used to power a variety of things, including the small light bulb on the end.

Rapidly spinning, highly magnetic neutron stars act as generators in much the same way! When magnetic neutron stars spin, they can produce voltages of over 1 trillion volts! Compare that to the tiny 12 volts your hand crank generator can produce.

Suggestions for introducing the activity:
Ask a volunteer to turn the crank on the hand generator, and observe the light bulb on the end. Have them crank slowly, and then more quickly. What happens? The faster you spin the coils of wire around the magnet, the higher the voltage and the more electric current is produced in the circuit that flows through the light bulb, so the brighter the light bulb can glow.

Procedure:
Ask visitors to look inside the clear generator and try to figure out how it works. Have them turn the crank slowly and peer inside the metal canister to spot the spinning copper coils of wire.

Discussion/Questions for visitors to consider:
What happens when you crank the coil of wire slowly? How about faster? When do you think the voltage would be higher?
Like the hand generator, rapidly spinning, highly magnetic neutron stars can produce high voltages and electric fields. Show visitors an image of a neutron star. If your hand crank generator can produce up to 12 volts, try to think about enormous magnetic fields and speed of a spinning neutron star that can produce over 1 trillion volts! How far do you think this voltage can reach? These neutron star generators can light up gas clouds in space that extend several light years! Two light years is about 12 trillion miles! Show visitors an image of the Crab nebula. There is a rapidly spinning neutron star at the center of the Crab nebula, too.

By the numbers:
- Voltage between the ends of an AA battery: **1.5 volts**
- Voltage generated by hand-held generator: **up to 12 volts**
- Arc Voltage of a welder’s spark: **25 volts** (very high current)
- Voltage discharged in a 1 mm spark between your finger and a doorknob: **about 3000 volts** (but very little current)
- Leyden Jar voltage: depends on its charge – but in general you can estimate 3000 volts per mm-length spark (e.g., if you get a one cm spark, that’s **30,000 volts**!
- Voltage released from cloud to ground in a lightning bolt: **100 Million volts**
- Voltage generated by a spinning magnetic pulsar in space: **1 Trillion volts**