Engineering and Imagination:
Helping Children Visualize the Invisible

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What is Engineering?

The application of science, mathematics, ***and imagination*** to solve problems.

How can we help children develop their technical imaginations?

We can provide multi-modal experiences (visual, physical, aural) to help them develop pathways for learning and thinking that involves their visualization of phenomena that can't be seen.

Gravity

- Gravity is a force that attracts us to the Earth, *but we can't see it*.
- Where is there less gravity than on Earth?
- What if we were on Jupiter, a planet much bigger than Earth?

Modes for Imagination Creation:

- **Visual (video)**
- **Physical (walking with more and less gravity)**

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

www.universetoday.com

Electricity in Circuits

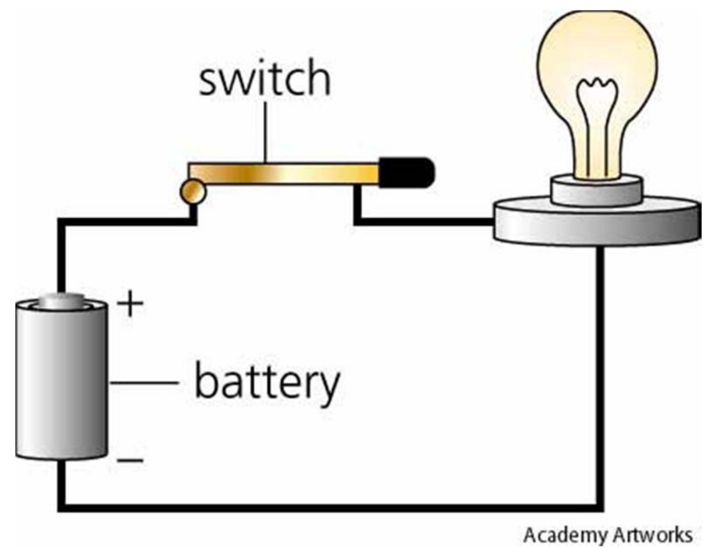
- What kinds of devices use electricity?
- *Electrons* are tiny particles that are much too small for us to see.
- To make our devices work with electricity, we need *circuits*.
- Every circuit has three parts – a source of electrons (battery), a pathway for the electron to take, much like a road, and a load (a light bulb).

Electricity in Circuits

- Show a real circuit and demonstrate.
- Use small balls as electrons and have children make a circuit. Turn a child into a switch!
- Catch the ball through the light bulb – if it drops, it got turned into light!

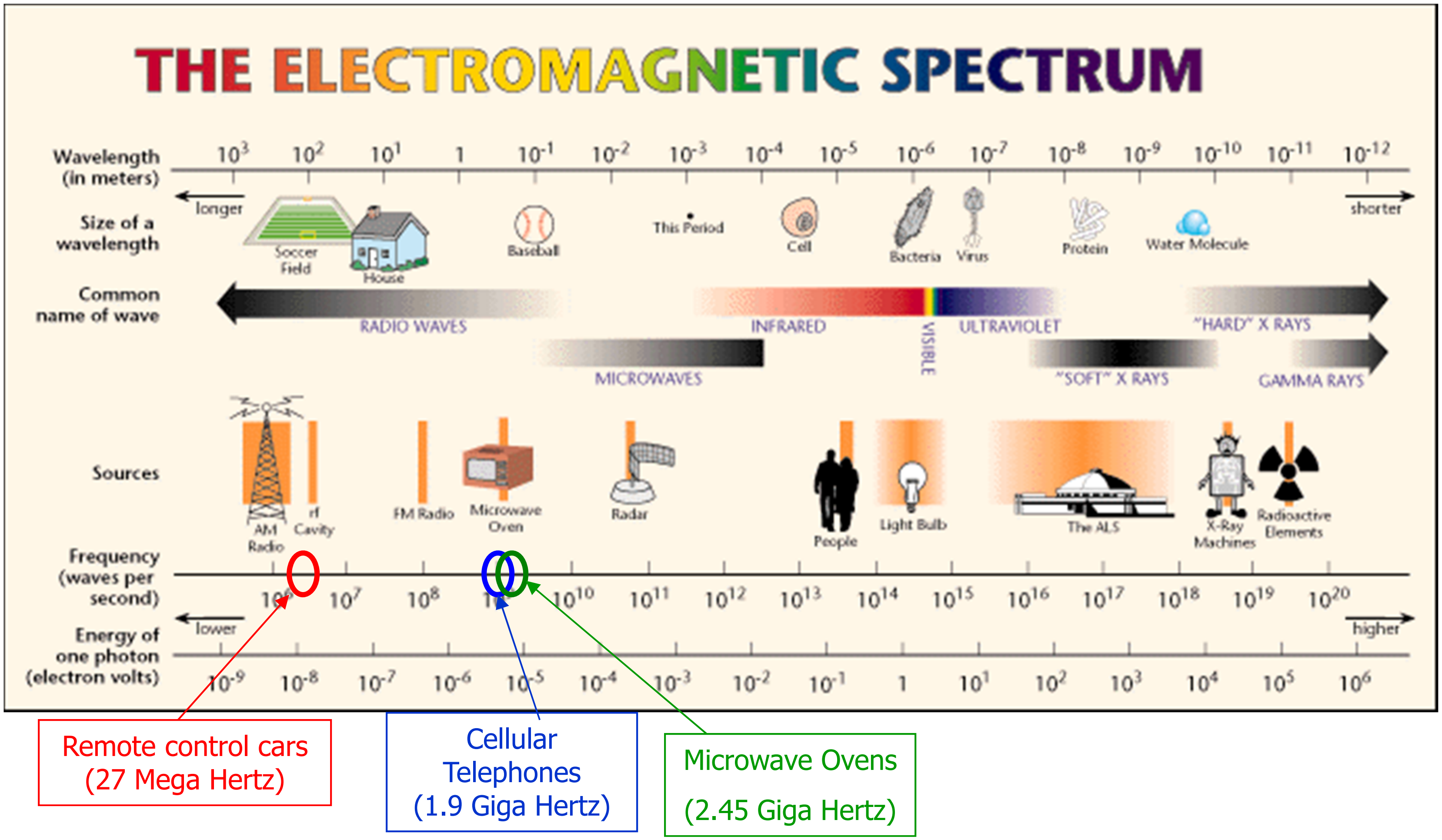
Modes for Imagination Creation

- **Relational (personal experiences)**
- **Aural (say, "electricity," say "circuit")**
- **Visual (demonstration)**
- **Physical (circuit participation)**



Electromagnetic Waves

- Electromagnetic waves are used to get an electrical signal from one place to another without having a long circuit between the two places.
- These signals are launched by antennas (using transmitters), travel through the air in the form of electromagnetic waves, and are collected by other antennas (using receivers).
- We can't see them with our eyes – *they are invisible* – but they are there – and we use them every day!


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20
lower
higher
Energy of one photon (electron volts)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10^1 10^2 10^3 10^4 10^5 10^6
Remote control cars (27 Mega Hertz)
Cellular Telephones (1.9 Giga Hertz)
Microwave Ovens (2.45 Giga Hertz)

Electromagnetic Waves

- What devices do you have at home that use electromagnetic waves?
- Electromagnetic waves are *transverse*, which means that they move up and down while the signal travels away. Say "transverse."

Modes for Imagination Creation

- **Relational (personal experiences, radios)**
- **Aural (say "transverse")**
- **Physical (jump ropes)**

payfitnessforward.blogspot.com

Sound Waves

- Another kind of wave is called longitudinal (say "longitudinal").
- Sound uses this kind of wave to travel.
- When our radio receives the electromagnetic signal from the radio station, the radio changes the electromagnetic wave into a sound wave so that we can hear it.

Modes for Imagination Creation

- **Relational (personal experiences, radios)**
- **Aural (say "longitudinal," radio)**
- **Physical (slinkies)**

en.wikipedia.org

Conclusion

- Using **imagination** is a fundamental part of **engineering**!
- Relating engineering concepts through multiple modalities may help children develop technical imagination skills that will help them develop natural affinities to process and visualize abstract concepts later.

And, it's lots of fun!

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<u>Electricity 1</u>

Objective: First activity introducing 3, 4 & 5 year olds to the concept of electricity and a circuit.

Supplies:
Large, clear plastic container with "+" and "-" marked on the side
Many ping pong balls
Demonstration circuit with a switch and a tiny light bulb
Barrier that serves as the "load" (Cardboard picture of light bulb with hole at the bottom through which to pass the balls.)

Presentation
Title the lesson Electricity in a Circuit.

Have the children say "Electricity."

Start by asking the children what kinds of devices run on electricity.

Today, we're going to see how electricity works, with the flow of electrons in a circuit, or in this case in a rectangle and in a circle.

Electrons are tiny charged particles that are much too small for us to see. Every circuit has three parts: a source of electrons (a battery), a pathway for the electron to take, much like a road (the circuit pieces) and a load (a light bulb). Sometimes there are also switches to turn the light off and on, just like the light switches at your house.

Here's a real circuit – it has a battery, a pathway, a light bulb, and a switch that will open or close the path. What is a circuit? A circuit is really just a closed shape – it could be a circle, or it could be a rectangle, like the circuit I have here. The electrons flow from the battery, through the pathway, to the light bulb, where they do a little work and make some light, and then go back to the battery down the rest of the path.

Today, we're going to use ping pong balls to represent electrons, and you are all going to be part of a circuit.

* Set up and show the "battery," which is a big source of ping pong balls (our electrons). Set up a barrier that represents the light bulb (which one of the children will have to throw the ball over for another one to catch and send around the circle) and later several people can be "switches."

Starting with the instructor at the battery, a child is given a ball and must pass it to the person sitting further down the circuit, and a child can only have one ball at a time.

First, we try it just with a circuit with no load attached. (Pandemonium ensues. Then quiet returns…)

Next, we just put in a "switch," which is a child that stops sending the balls around. What happens when the switch is "closed?" (The "electrons" can move around the circuit.)
What happens when the switch is "open?" (The balls get to a certain point and then then can't go any farther. Have multiple children be "switches" and try it.)

Now let's put a "load" into our circuit. For the real circuit, the "load" is a light bulb, which changes some of the energy from the electrons into light, which means that not all the electrons go back to the source (battery). For our circuit load, we're going to have a "wall" (a piece of cardboard) that one child must toss the ball over and have the other one catch it.

If the ball is caught, it continues on down the circuit. If it doesn't get caught, then that ball can't come back to the circuit (this ball got converted into "light.").

Eventually, this means that the source won't have any more electrons to give, and the battery will be used up. That's why you may have seen your parents replace batteries in things like toys, flashlights, and clocks. All of the energy from the electrons has been used up and there aren't any more available electrons to go around the circuit.

Next time we'll figure out what kinds of materials we can use to make our own electrical circuits!

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<u>Electricity 2</u>

Objective: Reinforce first activity introducing 3, 4 & 5 year olds to the concept of electricity and a circuit, and investigating what kinds of materials conduct electricity.

Supplies:
Large, clear plastic container with "+" and "-" marked on the side
Many plastic golf balls
Demonstration circuit with a switch and a tiny light bulb/sound maker
Voltmeter set to continuity check

Presentation
Title the lesson Conductors of Electricity

Have the children say "Electricity."

Review first electricity activity and have them repeat the word circuit.

Review that electrons are tiny charged particles that are much too small for us to see. Every circuit has three parts: a source of electrons (a battery), a pathway for the electron to take, much like a road (the circuit pieces) and a load (a light bulb). Sometimes there are also switches to turn the light off and on, just like the light switches at your house.

Here's a real circuit – it has a battery, a pathway, a light bulb, and a switch that will open or close the path. What is a circuit? A circuit is really just a closed shape – it could be a circle, or it could be a rectangle, like the circuit I have here. The electrons flow from the battery, through the pathway, to the light bulb, where they do a little work and make some light, and then go back to the battery down the rest of the path.

Last time, we used golf balls to represent electrons, and you were all going part of a circuit.

Now, let's see what kinds of materials we can use to make a real circuit, or pathway for the electrons to follow.

For the electrons to follow the path of our circuit, the material that makes up the circuit has to be **conductive**, or must be a **conductor**. Say "conductor."

Let's run a couple of experiments to see if materials can conduct electricity. First, let's try it with my old circuit. If I extend the path of the circuit to go through one of these materials, we can see if the electrons will flow through the circuit and light up the lightbulb.

First, let's try this piece of aluminum foil. The electricity will flow through the regular path and through the aluminum foil so that the electrons can get to the light bulb and light it up. (Try it and the light bulb lights.) This means that aluminum foil is a conductor.

Next, let's try this piece of foam. (Try it.) The light bulb doesn't light up when we try to put the foam in the circuit, so that the foam is not a conductor.

Here's another way to test to see if something is a conductor. This piece of equipment is called a voltmeter, and it has a circuit inside the case and the red and black leads are also part of the circuit. If we touch the leads to the aluminum foil, the voltmeter beeps, telling us that the aluminum is conducting. If we try it with the foam, it doesn't beep, telling us that the foam is not a conductor.

Now let's split up into two groups and do some testing of different objects that I brought today. Some of you can use the lightbulb circuit, and some of you can use the voltmeter. (Everyone should get a turn to try two objects – one conducting and one insulating.)

Do you think it matters what shape the material is in, or does it matter what the shape is made of?

All of the objects that are conductors are made out of metals – aluminum, copper, or brass are three examples of these materials. It doesn't matter what shape they have – it only matters if they are made of metal, because metals are good conductors.

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<u>**Electricity 3**</u>

Objective: Reinforce first and second activity introducing 3, 4 & 5 year olds to the concept of electricity and a circuit, and investigating the concept of series and parallel circuits

Supplies:
Large, clear plastic container with "+" and "-" marked on the side
Many plastic golf balls
Demonstration circuits with switches, tiny light bulbs/sound makers, in series and parallel configurations
Colored pieces of paper (sticky notes) to make "paths" for parallel and series circuits

Presentation
Title the lesson New Kinds of Circuits – SERIES and PARALLEL

Have the children say "Electricity."

Review first electricity activity and have them repeat the word circuit.

Review that electrons are tiny charged particles that are much too small for us to see. Every circuit has three parts: a source of electrons (a battery), a pathway for the electron to take, much like a road (the circuit pieces) and a load (a light bulb). Sometimes there are also switches to turn the light off and on, just like the light switches at your house.

Here's a real circuit – it has a battery, a pathway, a light bulb, and a switch that will open or close the path. What is a circuit? A circuit is really just a closed shape – it could be a circle, or it could be a rectangle, like the circuit I have here. The electrons flow from the battery, through the pathway, to the light bulb, where they do a little work and make some light, and then go back to the battery down the rest of the path.

A while ago, we used golf balls to represent electrons, and you were all parts of circuits.

Today, we're going to make two different kinds of circuits. SERIES circuits and PARALLEL circuits.

First, let's say "SERIES"

You already know about a **series** circuit, because we made them before. A **series** circuit is one that is made up of a single path to get from the "--" side of the battery to the "+"

side of the battery. If I break this series circuit, we can be certain that no electricity will flow because the path is incomplete.

Here's an example on my board – see the one path from the "-" side to the "+" side of the battery? If I take out a piece of the circuit, then no electricity will flow and the light bulb will not light up.

Now let's take a look at a parallel circuit. Let's say "PARALLEL." A parallel circuit is one that provides more than one path for the electrons to flow from the "-" side to the "+" side of the battery.

Let's make one on the board. I attach some extra pieces to the path so that now the electrons can go down one path with this light, or down the other path with this light. We say that these two paths are in PARALLEL because electrons can take either path to get back to the battery. If we have a parallel circuit and we break one of the paths, does the electricity still flow? YES! (One of the lights still goes on.) It works for both paths – if you break one, all of the electricity will flow through the other path. If both are attached, then electricity will flow through both paths.

Today, YOU will be the electrons, and we're going to make two different circuits out of these colored pieces of paper.

First, let's make a SERIES circuit. [Put down sticky notes for the whole circle to make one big path.] This big piece of colored paper is the battery, so as electrons we all want to leave the battery and go in our circuit path and then go around and around. Our series circuit is a big circle! Let's move around our circuit like electrons! What if I break the path right here? Does electricity flow? NO!

Now let's make ourselves into a PARALLEL circuit. [Add some sticky notes to make a parallel path back to the battery.] Now we've made two different paths to travel back to the battery. At the junction, you can decide which path you want to take, but we always have to head back to the battery in the same direction. Let's move around our PARALLEL circuit like electrons!

Now, what if I break the circuit here (in one of the parallel paths)? Will electricity still flow in our circuit? Do we still have a path back to the battery? YES, BUT NOW WE ALL HAVE TO TAKE THE SAME PATH.

Now we know the difference between SERIES and PARALLEL. Let's think about one more type of circuit that we all have in our houses. Everyone has a light switch in their house, right? If you turn off one light switch, do ALL of the lights go out, or just the one attached to the switch? Does this mean that our houses have SERIES or PARALLEL circuits in them? PARALLEL! RIGHT!

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Electromagnetic and Acoustic Waves

Objective: Electrical and Sound Waves: Introduce (ever so gently) the idea of electromagnetic and sound waves carrying information and energy over a distance

Supplies:
Jump ropes
Slinkies
Radio with antenna

Presentation
Title the lesson Electrical and Sound Waves

Have the children say "Electricity."

Remember when we did all of our electricity experiments with our electrons and our circuits? It turns out that we can also use a different form of electricity without needing a circuit. This form of electricity is called an electromagnetic wave.

Have the children say "Electromagnetic wave" a couple of times.

Electromagnetic waves are use to get a signal from one place to another without having to have a long circuit in between the two places. These signals are launched by antennas (using transmitters), travel through air in the form of **electromagnetic waves**, and are collected by other antennas (using receivers). We can't see them with our eyes – they are invisible – but they are there!

We all have devices in our homes that receive electromagnetic waves, like this radio. If we turn on the radio, sound comes out, but where has that sound come from? It comes from a radio station far away that is sending **electromagnetic waves** all over Champaign and Urbana. Then, with our radio, we catch this electromagnetic wave with our antenna (show antenna) and then the radio changes the electromagnetic signal into the music comes through the radio.

Electromagnetic waves are **transverse (say transverse)**, which means that they move up and down while the signal travels perpendicular (at right angles) to the direction of motion.

Let's illustrate this with the jump rope.

By moving the ends of the rope up and down, we can create wave on the rope. The wave travels from side to side, even though we're moving the ends of the rope up and down.

Another kind of wave is called a **longitudinal** (say longitudinal) wave. Sound (acoustics) uses this kind of wave to travel. When our radio receives the electromagnetic signal from the radio station, it changes it into a sound wave so that we can hear it.

We can illustrate this with a slinky.

Here, we move the ends of the slinky back and forth from left to right, and the wave also moves along the same line – back and forth. This is what makes the wave longitudinal.

Let's all try to make some waves, both transverse (electromagnetic) and longitudinal (sound/acoustics).

So, our radio is using both kinds of waves – electromagnetic waves to get the songs from the radio station, and then sound waves to get the music from the radio to our ears!

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Gravity

Objective: Introduce 3,4,&5 year olds to gravity as a force. Additional concepts – different planets have different gravities.

Supplies:
Video of moon walk

Presentation
Title the lesson Gravity.

Gravity is a force that pulls things toward our planet. What things? (Get contributions) Everything!

What would happen if we did this on the moon?

Watch video of people walking on the moon.

The moon is smaller than the earth and has less gravity, so things feel lighter. Planets that are bigger than Earth, like Jupiter, have more gravity, so things feel heavier.

Active part – stand up and move around in a circle. Walk around in a circle normally. Then pretend you are on the moon and your body feels really light. Then pretend you are on Jupiter and your body feels really, really heavy.