Orders of Magnitude - POTATO POWERED COSMOS

A CONSTRUCTION MANUAL -- Just add water. By Rachael Nee

Photo credit : Gorm Ashurst

Introduction: artist statement

Physicist Richard Feynman had a short anecdote called Ode to a Flower , in it he compares what an artist can see, in comparison to a scientist, when looking at a flower. The aesthetic beauty the artist sees, he said, is available to himself and to all others. However, a scientist can see many other layers, for instance the 'beauty' of structure and processes that make the flower.

Is this true? As artists can we only have a shallow appreciation of the nature of things? Is a lack of high levels of maths and physics too much of an inhibitor? Perhaps the answer lays somewhere in the middle, the best of both worlds with art produced from bringing the two cultures together. Starting with a statement, what follows is a construction manual for the artwork made in response to several days at CERN in 2015 with the support of art@CMS and University of the Arts, London.

You will be able to reconstruct the installation and then take it forward with your own fresh research, thoughts and ideas. I hope you will find this project playful and fun; and in the process learn a little bit about the fertile territory around the interface of science and art, as did I.

In essence, I used the idea of the energy potential of a potato (as found in the CERN canteen) and took it to absurdity. The canteen in CERN is an important meeting place, where scientists meet and collaborate with others from all over the world, so the potato becomes, literally, food for thought.

THE HYPOTHOSIS - Potato Powered Big Science

Scale is unavoidable in CERN; scales at the extremes of space, time, knowledge, collaboration, finance and energy. The website states that *"CERN uses 1.3 terawatt hours of electricity annually, enough power to fuel 300,000 homes in the UK."*

Is there not a cheaper, more sustainable and renewable energy source to probe the fundamental structure of the universe?

Building on published investigations,[i] I tested the hypothesis of boiled potatoes as an alternative, with the experiment *'Orders of Magnitude – Potato Powered Cosmos.'*

The Large Potato Field Array produced 5 volts and 40 milliamps for one hour during the observer-activated tests. These revealed several key events indicating fundamental forces of nature were seen; from this we can extrapolate the universe was observed in a puddle. Further research into feasibility requires scaling up the potato Array. Evidence suggests that 11.13 x 10^9 kg of potatoes could fuel CERN for an hour.

Alternatively, if eaten, the experiment's potatoes would power 6.3 average-sized scientists for a day.

THE ENERGY – 'powering the cosmos'

The Potato Battery

The huge amount of energy needed to operate CERN is produced predominately by EDF in France at nuclear power stations. We will be working towards producing our own power at the opposite end of the scale (order of magnitude) – milliamps.

In Experiment 1 we will work out the best cooking time to produce the most current, then how to assemble the battery cells. In Experiment 2 we will work out the most efficient arrangement of the battery cells in parallel or/and series to operate the amplifier.

Within the artwork the potato also has a use as another type of energy source – food; carbohydrate 'fuels' the humans/scientists to experiment, measure, theorise.

KEY WORDS: CATHODE, ANODE, ELECTROLYTE, BATTERY, RESISTANCE

Potato Battery Materials:

- Copper sheet
- Galvanized zinc sheet
- Alligator clips
- Wire – red and black
- Elastic bands
- Potatoes (other fruit and vegetables ie. Lemons)
- soldering iron and solder
- wire cutter/stripper
- pliers
- multimeter

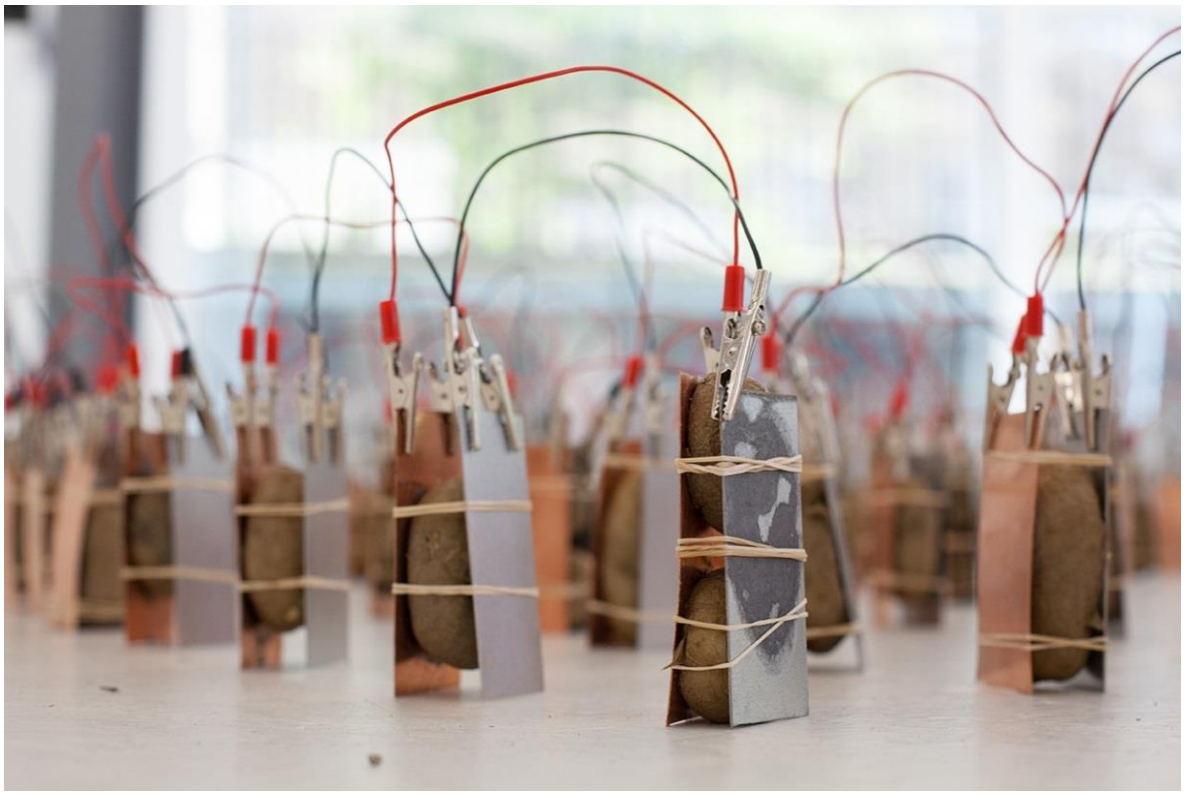


Photo credit: Gorm Ashurst

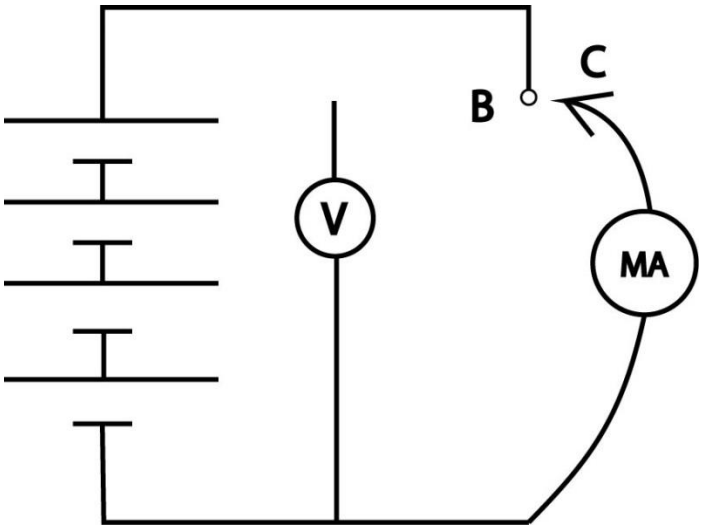
IMPORTANT: During all the experiments please take notes, photographs or sketches. Jot down any thoughts or ideas you may have, they will be useful for the development of your own artwork.

Experiment 1

BOILING POTATOES (for 13-16 year olds)

Use potatoes of approximately 230-250g each. Each cell in the diagram is a slice of potato with the + terminal being a copper plate, and the - side being the zinc plate.

Note: If you build the full installation you can use any size of potato, just adjust cooking temperature accordingly, for instance, two small ones can fit in one battery cell.



You need to compare the readings of current values (microammeter readings) and corresponding pd across the battery (voltmeter readings), on open circuit and when C is quickly touched on to B, with the amount of cooking the potatoes have had.

There are two readings for each event, a and b, in order to gauge reliability.

TABLE OF READING:

Amount of cooking	OPEN CIRCUIT pd across battery [V]	B CONNECTED TO C pd across battery [V]	I * 10^{-6}A [micorA]
RAW	A	A	A
	B	B	B
Boiled for 4 minutes	A	A	A
	B	B	B
Boiled for 8 minutes	A	A	A
	B	B	B
Boiled for 12 minutes	A	A	A
	B	B	B

Make your own conclusions about the suitability of potato samples, raw or cooked.

Assembling the Cells

1. The Metal
    a. The zinc acts as the positive (+) anode and the copper as the negative (-) cathode.
    b. Cut the metal plates to size (10 x 6cm)
2. Assembling the individual cells
    a. Cut the ends of the potatoes off along the longer side (you can use several small instead of one large also)
    b. Sandwich between one plate of zinc and one plate of copper
    c. Wrap 3 elastic bands around as tightly as possible
    d. Make sure the 'cell' stands upright firmly.
3. Wiring
    a. Crimp or solder alligator clips to both ends of red and black wires of at least 20cm.

Experiment 2

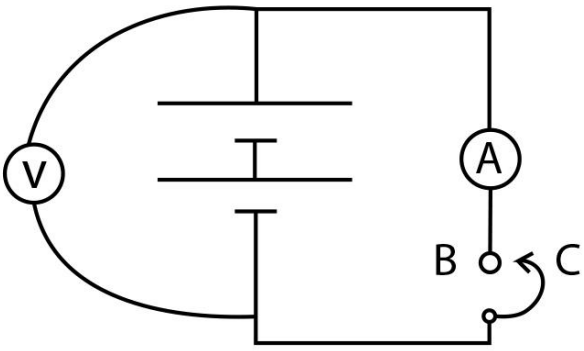
ARRANGEMENT OF CELLS (for approx 17 year olds)

Both TEST 1 and TEST 2 require1.5v cells. TWO are needed for TEST 1 and FOUR are needed for TEST 2.

The potatoes (or other fruits/vegetables) need to be arranged in the best possible way in order to be as useful as possible. In the artwork 'Potato Powered Cosmos', the potato array is a combination of series and parallel connections. (Energy for the LHC and for CMS is not provided by potatoes! It comes from EDF and generators in France.)

TEST 1

1. Set up the circuit above. Terminals B and C are initially not connected.
2. Record the voltmeter reading when B and C remain unconnected - when the push button switch is not closed.
3. Now touch C on to B for a short time (or push the push button switch) - just long enough to record the current (i) reading on the ammeter and the pd across the cells (V meter reading) - readings a) in the table. ENSURE THAT THE CONNECTION IS NOT MADE FOR LONGER THAN



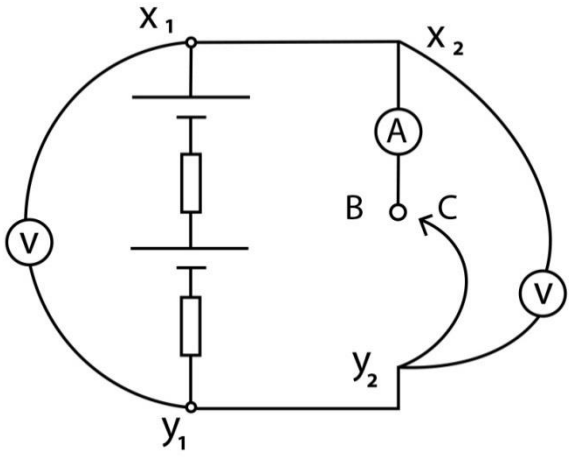
ONE SECOND OR SO.

1. After a short time, repeat. These are readings b) in the table.

TABLE of READINGS: Two 1.5v Cells in Series

OPEN CIRCUIT	**B and C CONNECTED**	**B and C CONNECTED**
pd across cells [V]	pd across cells [V]	i in cells [A]
	a)	a)
	b)	b)

Analysis

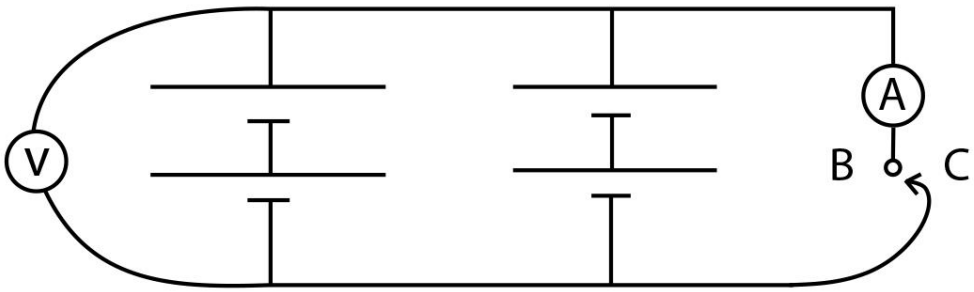
The cells each have some resistance. All components do. These resistors are not shown in the circuit diagram above. If they were shown, the circuit diagram would look like this: The voltmeter connection can be "seen" as being between X1 and Y1, or between X2 and Y2. X1 and X2 are the same points electrically. So are points Y1 and Y2.	

Question

If each cell has an emf (maximum voltage possible) of 1.5V and an internal resistance of 0.5 ohms, what is the maximum current which could be in the circuit above, when B and C are connected together, in effect 'shorting' the battery?

TEST 2

Now connect FOUR cells together as shown;



Repeat the procedure as for TEST 1.

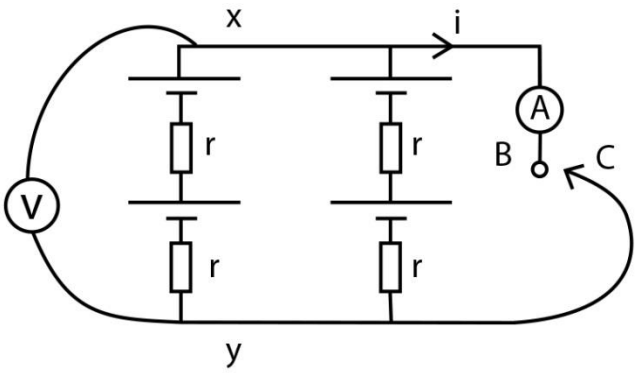
TABLE OF READINGS

Two Lots of 3.0v Batteries Connected in Parallel

OPEN CIRCUIT	**B and C** **CONNECTED**	**B and C** **CONNECTED**
pd across batteries [V]	pd across batteries [V]	i in cells [A]
	a)	a)
	b)	b)

Analysis

Each of the four cells has a resistance associated with it (called internal resistance), so the circuit should really look like this:



pd is pd across left-hand battery
^{xy} **and** pd across right-hand battery.
It is the same pd!

Question

If the emf of each cell (maximum voltage across each) is 1.5V and each internal resistance is 0.5 ohms, what would the maximum value of the current (i) be, when C is connected to B? (Remember the resistances 2r and 2r are connected in parallel, and therefore the battery has a combined resistance of r! This is probably about 0.5 ohms!

COMPARE THE RESULTS OF TEST 1 AND TEST 2.

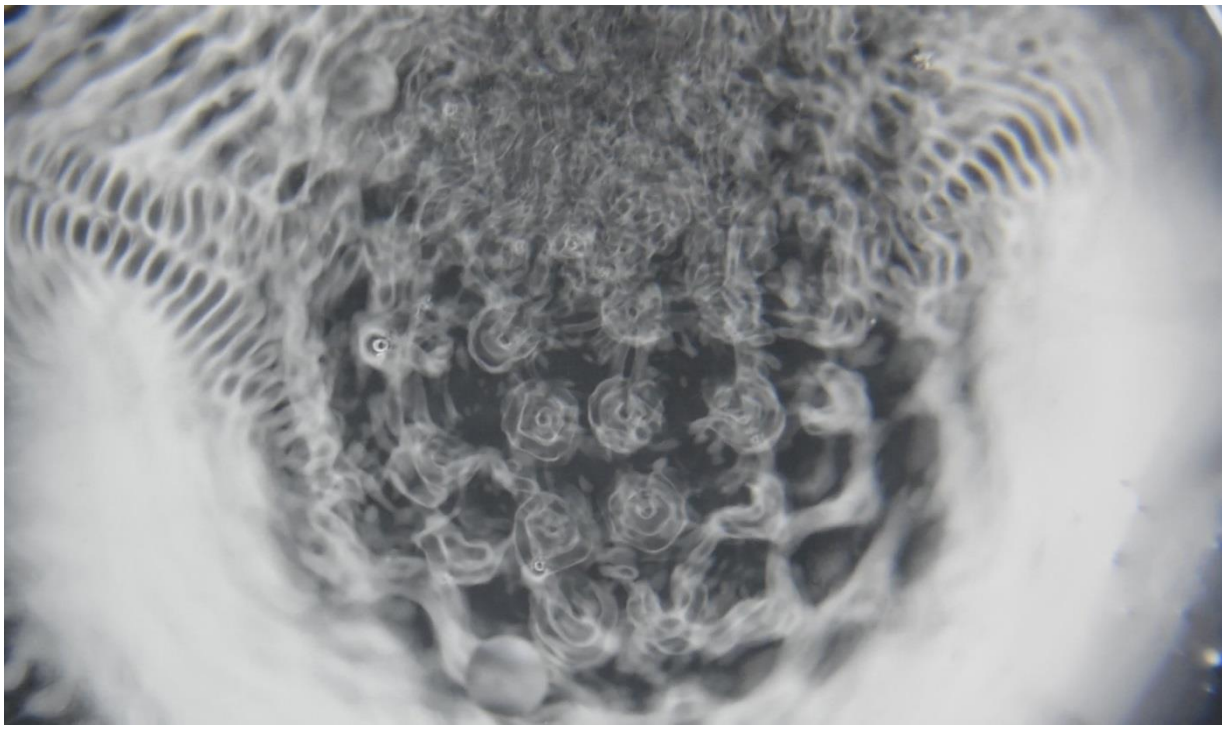
WHAT IS THE ADVANTAGE OF HAVING TEST 2's CIRCUIT AS OPPOSED TO TEST 1's?

(IN OTHER WORDS, WHY USE FOUR CELLS WHEN THE OPEN CIRCUIT PDs ACROSS BOTH BATTERIES (OF TEST 1 and 2) IS THE SAME?)

Other Experiments you could do:

1. **How long will the potato last? Make a graph of current and voltage over a few days to see what happens, KEY WORDS; OXIDISATION, REDUCTION**
2. **What other vegetables or fruits could be used? Why is there a difference? Why does cooking a difference? KEY WORD: ELECTROLYTE.**
3. **Try different metals to see the difference in current for instance stainless steel or brass, KEY WORD: STANDARD ELECTRODE POTENTIAL**
4. **How many boiled potatoes would it take to 'power' you for a day? KEY WORDS: CARBOHYDRATE, KILOJOULES**

THE EXPERIMENT – 'Discovering the Cosmos'



Puddle Universe

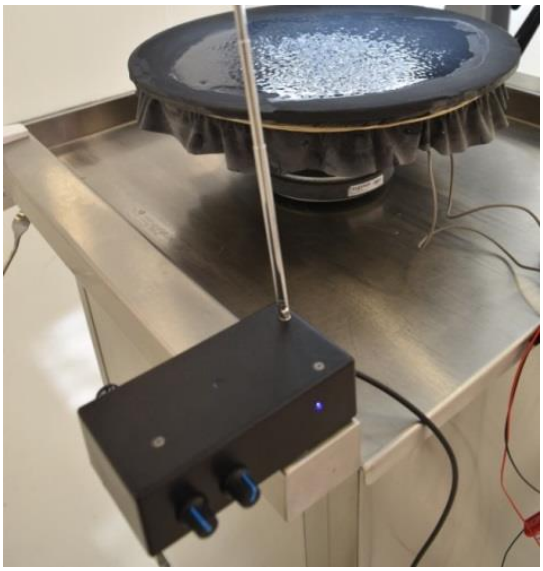
In the experiment we 'create the cosmos' in a puddle by using a Theremin or Signal Generator, amplifier and speaker. This creates a variety of patterns through standing waves; this in turn reflects some of the fundamental forces of nature, the discovery of which is an aim of CERN.

KEY WORDS: STANDING WAVES, SINE-WAVES, NODES/ ANTI-NODES, FREQUENCY, VIBRATION.

Cosmos Experiment materials

- Kemo DC amp (6V– 12V)
- Cable with 1/4in jack plug and phono connector (amp to theremin)
- Theremin
- Loudspeaker
- Signal Generator or tone generator ‘app’ downloaded to computer or mobile phone.
- 9v batteries, snap battery clip
- Latex rubber sheet (enough to cover speaker so it overlaps)
- Water and other materials with different viscosities, for instance; runny and solid jelly, oil, fine-grained sand.
- Ear protectors (for high frequency)

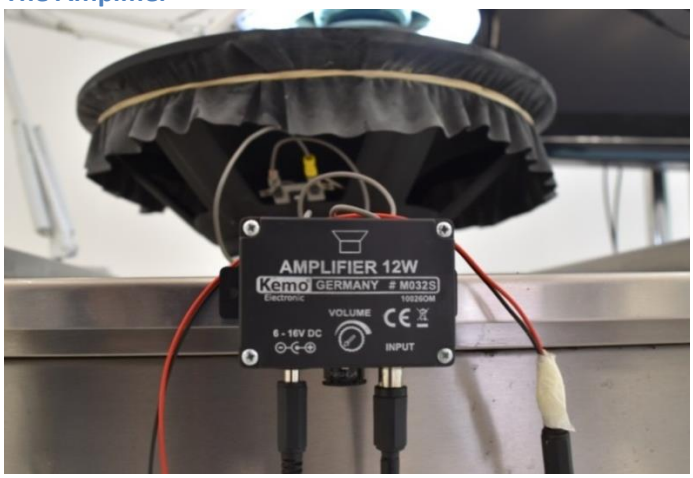
The Theremin



The Theremin is a musical instrument (often heard in old science fiction movies) that is operated by proximity and position of the musicians hands. Within the installation its role is to be activated by the presence of a viewer/observer, this ‘completes the circuit’ to make the sound that creates the standing waves patterns.

For a video of how a Theremin works follow this link. - http://bit.ly/23OD36b

Key words: Oscillator, Capacitors

The Amplifier 	**Question:** **Why does the artwork use a DC and not AC/DC amplifier?**
The Speaker 	**KEY WORDS:** **OHMS, WATTS, MEMBRANE**

EXPERIMENT 3

Explore different frequencies by using a Theremin, signal generator or a tone generator downloaded onto a mobile phone or computer.

Connect the speaker, amplifier (powered by 9V battery) and Theremin or Signal generator.

Put on the latex membrane and tighten so surface is taut.

Cover latex with a layer of water extending nearly to the edge.

- **If using signal/tone generator, run a sinewave up and down from 1hertz (1 Hz = 1 second), wear ear defenders if it gets too loud.**
- **Explore sine, triangle, sawtooth and square waves, is there any difference?**
- **If using a Theremin experiment with volume and pitch by using your hand or body in proximity to the antennae of the Theremin until. (See front page image). How far can you stand away? What movements can you make? What difference does a group of people make?**
- **What happens if you use more water?**

EXPERIMENT 4

Materials.

- **Experiment with different materials on the latex; oil, paint, different viscosities of jelly, cornflour and water, sand, what else can you find?**
- **How about different materials at the same time? How do they interact with each?**
- **Try different surfaces; does the tension of the latex make a difference, what happens if you substitute shallow plastic bowls, or another rigid surface.**
- **What other ways can you explore the materials?**

OBSERVATION – observing the cosmos.

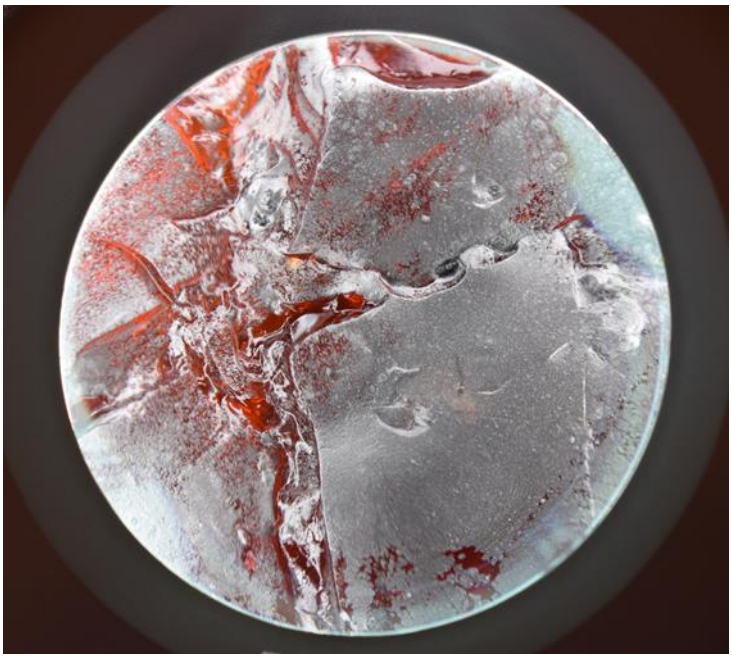
The Observation part of the installation references CERN in that the detectors can be seen as giant cameras. The camera in the artwork has been set up to show all the different measurements used in making the image, for instance shutter speed and aperture size, all measurements concerning how the camera 'observes' the image. The magnifying light increases the scale of the standing waves so they can be seen and the digital data information is not seen directly but mediated through the TV monitor. This is a parallel to CMS, where all data from the experiments is seen in 'real-time' on screens in the Control room but the experiment is not observed directly.

Observation and measurement are important concepts in quantum physics. It states how the act of observing changes the outcomes the object observed.

Does the observer have to be human? If metal kitchen unit is used, this too can be 'played' by touching the metal. Watch the dog, 'Samson plays the Theremin' with the QR code:

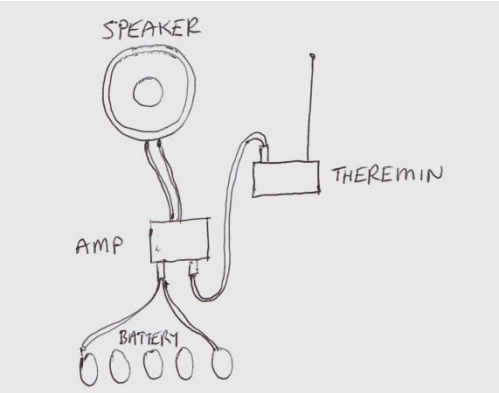
The Observation Station – equipment

a. Magnifying lamp
b. Camera with 'live view' or camcorder, to project in real-time.
c. Monitor/TV
d. AV cable
e. Stainless steel kitchen unit.
f. Human (preferably potato powered)
g. The speaker amp experiment



Assembling the whole installation

Assembling the Theremin, Amp and Speaker



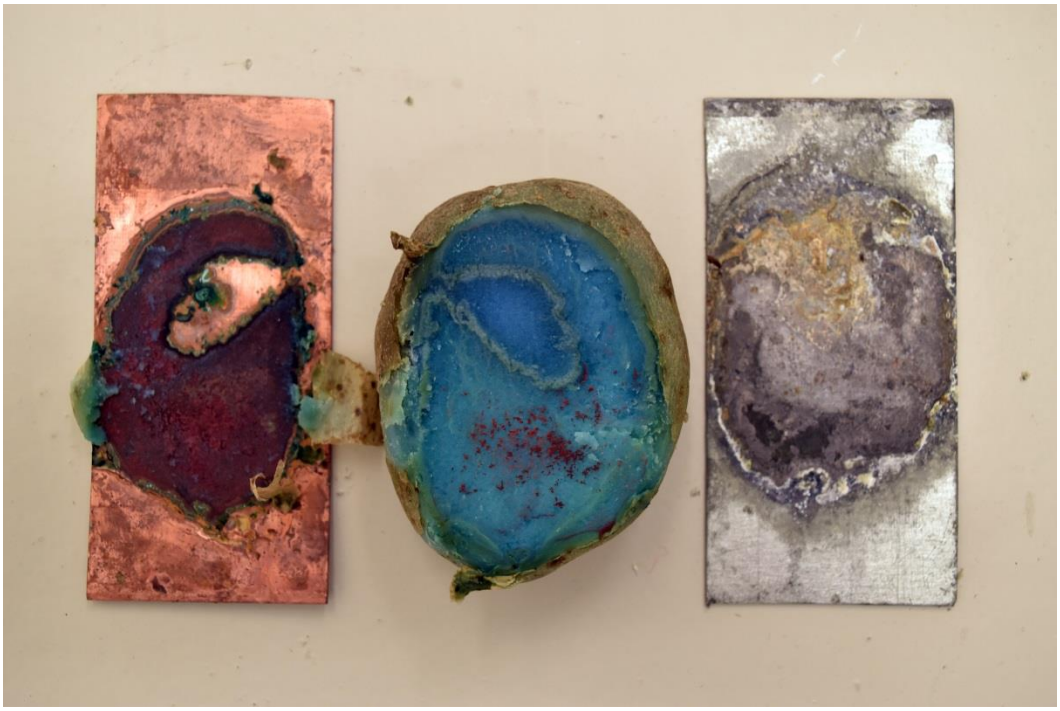
a) Put speaker, Theremin and amp onto kitchen unit.
b) Connect amplifier to speaker
c) Use cable with phono and ¼ in jack to connect Theremin to amplifier.

- Arrange the potato battery array in configuration already worked out, Attach latex sheet to speaker with elastic bands around circumference, manipulate it to make as taut as possible.
- Attach magnifying light to unit
- set the tripod up with the camera facing down through the magnifying lamp
- connect the camera to TV monitor

It's rechargeable too!

Wire a 9 volt battery into the potato array circuit for an hour or two, (then remove) if not enough energy is being produced to make standing waves. You will find your potatoes have been invigorated to work again. Why is this?

Eventually the battery will no longer produce enough energy to run the experiment. Below is a 'cell' opened (after four days) to reveal the potato has turned a beautiful blue on the copper side. What reaction has taken place?



Opened used battery 'cell' showing copper reaction

RESEARCH

In preparation for working on your own art research and artworks I have written the following about the process of how I approached making Potato Powered Cosmos.

Art Research

Making the artwork started with looking for answers to questions that came up as a result of the CERN visit, material collected during the visit, including photos and talking to people and then tying those together with my own research interests. Potato Powered Cosmos was not the first idea, but a result of rejecting other false starts, dead-ends and things unfeasible in the timescale given or just simple loss of interest. This is a normal part of the process; ideas rarely come fully-formed. Working with and manipulating materials 'hands-on' also helps create new ideas.

1. What were the main questions?

    a. How to overcome the problem of having limited scientific knowledge and understanding of the subject.
    b. How to make a physical/material artwork from the seemingly immaterial and data heavy subject matter.

2. What are my art research interests?

a. Energy, entropy,
b. Matter and materials
c. Process and experiment over finished product.
d. Art Installation as research experiment
e. Using science to create a fiction.

3. Collecting research - my Cern visit - areas of interest to develop

a. Website research, energy and CERN has an environmental cost.
b. Audio - Mains hum from transformers in CERN influenced me to use sound.. (get audio from cern?) https://www.youtube.com/watch?v=QhE5OSp0aHE
    i. Research sine waves, Hertz, KHz
c. Human element –
    i. Importance of restaurant as hub
    ii. Talk with theoretical particle physicist and others.
    iii. Fabiola Gianotti – talking about cooking and music and its relation to science
d. Scale – Orders of Magnitude
    i. Fundamental particles, fields and forces to cosmic scale
e. Combining systems/networks human and scientific machine
f. Parallel between LHC energy use and people energy.
g. Relationship between energy used at CERN and environmental cost.
h. Relationship between experiment and theory

1. The Process – interrelation of theory, research and experiment

The Whiteboards showing progression of the idea and sticky notes of key words, terms and quotes.

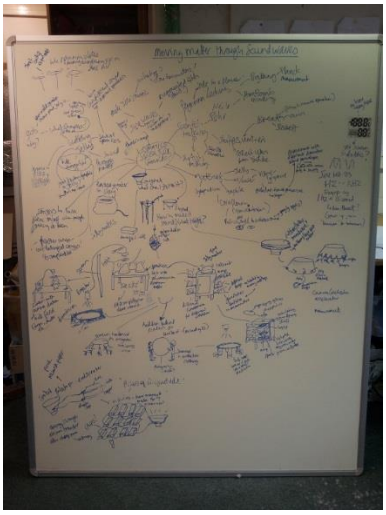


Figure 1. Progression of idea

Figure 3: key words, ideas and quotes sticky note board and detail.

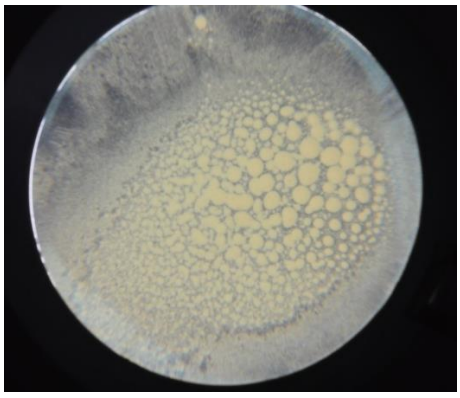
Figure 4: Drawing - working out the inter-related systems of Cern.

Experimenting with materials and equipment

I experimented and made many videos with different materials and soundwaves as in Experiments 3 and 4. A video compilation of materials research can be found using this QR code.

The installation continues to be an ongoing process of research. Below are some images of the very first experiment on jelly, then lycopodium powder, through to a recent lemon 'upgrade. The booklet ends with the discovery of a window into the early universe, found in a used battery cell: *Potato Hubble*.

Moving matter by sound - jelly



Lycopodium powder

Lemon 'upgrade' to test for increased voltage and current

Science and Art

Science and contemporary art have similar methodologies involving; investigation, research, testing out of ideas and theories through experiment.

In both there is an ongoing dialogue between experiment and theory. An example of this relationship in the process of making this installation - The problem: Sine Wave generator is too loud to be sustainable in a public space. Research led to Theremin (overcoming high Khz noise) which led to interactive nature of installation; led to changed material use as only water could be vibrated with Theremin.

ART PROJECTS – WORKING WITH YOUR RESEARCH AND IDEAS

Throughout the experiments phase of this project you will have been taking notes, photos, sketches, you may have found that ideas bubbled up. You may have thought of ways in which you would like to change the experiments, do them in a differently or concentrate on one element and research it some more.

Perhaps you could see potential in using other ‘electrolytes’ liked a lemon to produce power, follow this line of thought, what other materials could produce energy? What else could you power, some electronics, led lights, could you create another ‘machine’?

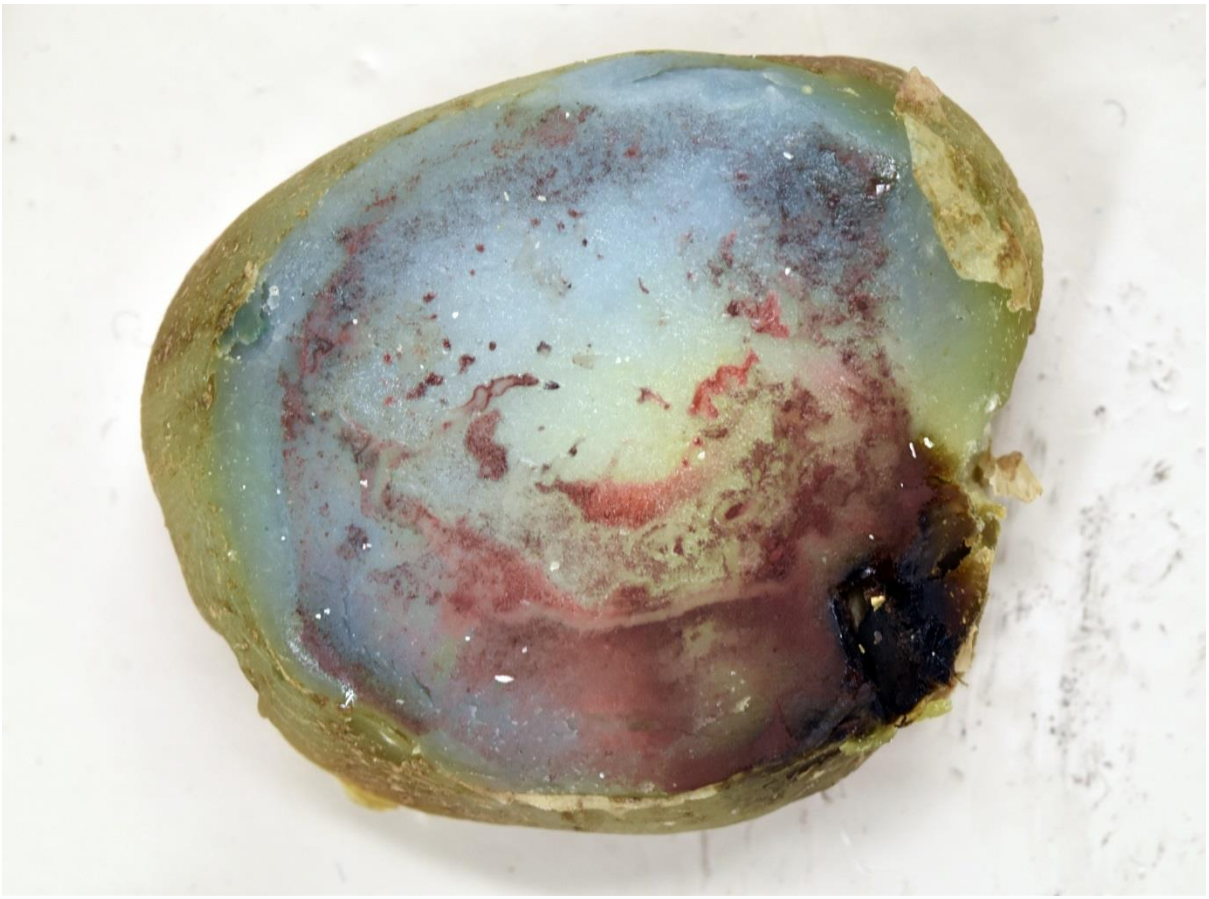
Maybe the theory interests you more and you’d like to do more research into the scientific or artistic concepts to inform your artwork like energy, space and time? Perhaps the beautiful patterns semi-viscous jelly makes caught your attention to look at symmetry or geometry.

How can you progress these ideas? Could they be translated into other artistic media; what about a short film, do some drawings or paintings. Perhaps you could create a dance with the Theremin? Or take a paper print from paint that has intermingled on the latex.

What about a sound art piece, working with tones and frequency?

In CERN people work together on projects, how about making a collaborative artwork with a partner or group?

Expect mistakes and false starts, even Particle Physicists have to abandon theories sometimes! Most of all get stuck in, have fun, play around with materials, and the ideas will come.



Potato Hubble

REFERENCE MATERIAL

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- 'Powers of Ten' – Charles and Ray Eames, 1977 – (about orders of magnitude) https://www.youtube.com/watch?v=0fKBhvDjuy0
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- Fabiola Gianotti - https://www.theguardian.com/theobserver/2014/nov/09/fabiola-gianotti-new-director-general-cern

Key Art Concepts

- Interactive Art - http://www.tate.org.uk/learn/online-resources/glossary/i/interactive-art
- Kinetic art - http://www.tate.org.uk/learn/online-resources/glossary/k/kinetic-art
- Installation Art - http://www.tate.org.uk/learn/online-resources/glossary/i/installation-art
- Entropy in Art - http://www.tate.org.uk/learn/online-resources/glossary/e/entropy

Artists

Historic, modern and contemporary artists influenced by science in a wide range of approaches. These include; collaborations with scientists, mixing scientific theories with fiction, myth and imagination, experiments with materials, visualisations of data from CERN, to sculptural interpretations of scientific concepts.

- Leonardo da Vinci – Well-known for his research and inventions in several scientific fields. https://en.wikipedia.org/wiki/Science_and_inventions_of_Leonardo_da_Vinci
- Marcel Duchamp – His playful interest in science and mathematics made him one of the most important and influential modern artists. https://en.wikipedia.org/wiki/Marcel_Duchamp
- Naum Gabo – interest in physics and engineering in first half of twentieth century http://www.tate.org.uk/art/artworks/gabo-kinetic-construction-standing-wave-t00827
- Joseph Beuys (energy)- http://www.walkerart.org/archive/4/9C4311B2C56C80996167.htm
- Ryoji Ikeda - http://www.ryojiikeda.com/
- Semiconductor - http://semiconductorfilms.com/
- Olafur Eliasson - http://www.olafureliasson.net/
- Tomas Saraceno - http://tomassaraceno.com/
- Liliane Lijn - http://www.lilianelijn.com/
- Agnes Meyer Brandis - http://www.blubblubb.net/
- Roger Hiorns – 'Seizure' http://www.ysp.co.uk/exhibitions/roger-hiorns-seizure
- Conrad Shawcross - http://conradshawcross.com/
- Katie Paterson - http://www.katiepaterson.org/
- Oron Catts - http://www.symbiotica.uwa.edu.au/residents/catts
- Keith Tyson - http://keithtyson.com/
- Luke Jerram - http://www.lukejerram.com/

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- **art@CMS** - http://artcms.web.cern.ch/artcms/
- **European Digital Art and Science Program** - http://www.aec.at/artandscience/en/about/
- **Ars Electronica** - http://www.aec.at/news/en/
- **Leonardo – The international Society for the Arts, Science and Technology** http://leonardo.info/index.htmlJournal
- **Symbiotica** - http://www.symbiotica.uwa.edu.au/
- **Science Gallery**, Dublin, Ireland - https://dublin.sciencegallery.com/events
- **Science Museum**, London - http://www.sciencemuseum.org.uk/
- **Wellcome Collection**, London - https://wellcomecollection.org
- **GV Arts,** London **-** http://www.gvart.co.uk/
- **Arts Catalyst** - http://www.artscatalyst.org/

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art@CMS_sciARTbooklet: web page : http://artcms.web.cern.ch/artcms/

A tool to support students with their research on various scientific topics, encourage an understanding of the relevance of expression through the arts, a manual to recreate the artwork and enable students to define and develop their own artistic inquiry in the creation of new artworks.

The **art@CMS sciART** booklet series directed by Dr. Michael Hoch, michael.hoch@cern.ch scientist and artist at CERN