1. Introduction

Tesla coil is the invention of Nikola Tesla. Its main function is production of high voltage low current high frequency AC.

The tesla coil was patented by Nikola Tesla on April 25, 1891. He took lecture on topic "Experiments with alternating currents of very high frequency at their Columbia College. Tesla had patented many similar circuits.

At the early stage when high frequency current was not known, direct current and low frequency currents were used. After the invention of Hertizian waves or radio waves having frequency above 20 KHz, by heinrich hertz, more number of scientists started experimenting with high frequency currents.

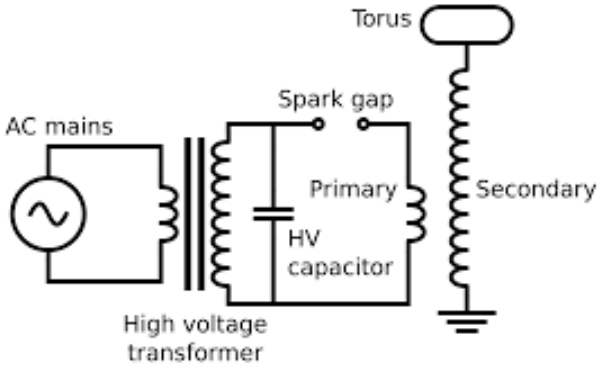
At the end of 19th century. Alternators were used as source of high frequency current invented by tesla. Then tesla moved towards spark excited resonant circuits applying resonance to transformers. These transformers were causing eddy currents and hysteresis loss. So, a new type of transformer came into existence called "oscillation transformer" that was without an iron core.

The tesla coil was invented during the development of ' wireless' lighting system with gas discharge light bulbs. Tesla changed the design of tesla coil due to problems occurring

with insulating material and replaced it by air. After, experimenting with Ruhmkorff circuit he found satisfactory result when the closed primary circuit with the capacitor was in resonance the open secondary winding.

Not only Tesla but Henry Rowland and Elihu Thomson experimented with this circuit which was able to give 1.6 m spark. However Tesla was the first to patent it.

2. Schematic diagram:



3. Components:

1. Neon sign transformer (NST)
2. Primary capacitor
3. Spark gap
4. Primary coil
5. Secondary coil
6. toroid

1. Neon sign transformer (NST):

Neon sign transformer is transformer use for purpose of powering neon sign like tesla coil. These transformers convert low voltage from 230V to high voltage in range of 2 to 15KV .They supply between 18-60 mA current. In our project we use neon sign transformer with 9kV, 30mA.normally NST available with GFCI circuit but for our purpose we take bypass GFCI circuit NST. It is very costly component in our project.

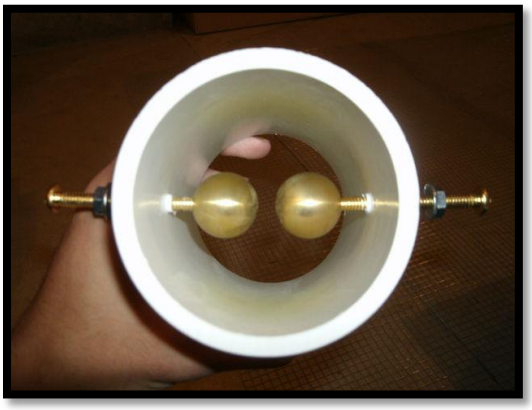
2. Primary capacitors:

The primary capacitor is used with primary coil to create primary LC circuit. This capacitor is usually made up of several dozen caps connected in series/ parallel called multi mini capacitor (MMC).

Most popular capacitor for tesla coil is Cornell dubilier 942C20P15K with 2000VDC and 0.15MFD. But cost of this capacitor is more

Sometime homemade capacitor also used including salt water beer bottle caps, rolled aluminum foil caps and stacked plate caps. But it is less efficient and required lot of time to build it.

3. Spark gap:



The spark gap is used as a switch to momentarily connect the primary capacitor to primary coil. When gap is shorted the capacitor is allowed to discharge through coil.

Basically two type of spark gap are used 1.static and 2.rotary. Mostly static spark gap consisting of bolts act as electrodes. It must be smooth and rounded without sharp edges.

4. Primary coil:

The primary coil is used with the primary capacitor to create the primary resonance circuit. The coil couples to the secondary coil to transfer power from primary to the secondary circuit. Primary coil is made by ¼ inch copper tube. We use 6AWG solid copper tube. And ¼ inch spacing leave between turns.

5. Secondary coil:

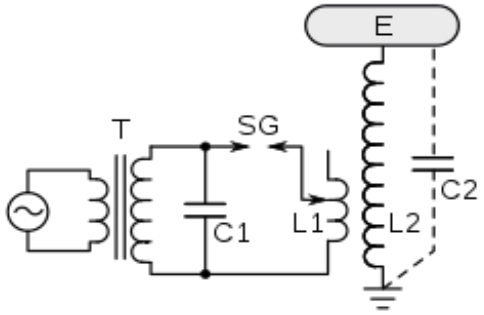
The secondary coil and toroid create secondary LC circuit. The secondary is also couples to the primary coil. The size of the secondary coil is mostly depends upon power supply. Average diameter of secondary coil is 3 to 6 inch and its height should be 4 to 5 times the diameter. The secondary wire is typically thin (22AWG to28AWG) magnet wire.

6. Toroid:

The toroid is acts as a capacitor in the secondary circuit. If toroid is small then it will produce many simultaneous shorter arcs. As size of toroid increase than number of arcs decrease but its length increase. We use aluminum dry duct pipe around pie pen to construct toroid. Its allover diameter is 4 times pipe diameter.

4. Working

The spark gap initially appears as an open-circuit. Current from the HV power supply flows through a ballast inductor and charges the primary tank capacitor to a high voltage. The voltage across the capacitor increases steadily with time as more charge is being stored across its dielectric.



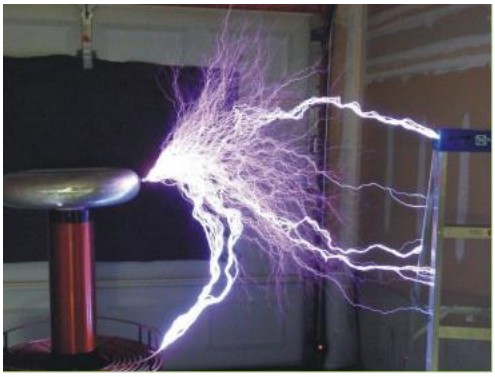
Eventually the capacitor voltage becomes so high that the air in the spark gap is unable to hold-off the high electric field and breakdown occurs. The resistance of the air in the spark gap drops dramatically and the spark gap becomes a good conductor. The tank capacitor is now connected across the primary winding through the spark gap. This forms a parallel resonant circuit and the capacitor discharges its energy into the primary winding in the form of a damped high frequency oscillation. The natural resonant frequency of this circuit is determined by the values of the primary capacitor and primary winding, and is usually in the low hundreds of kilohertz.

During the damped primary oscillation energy passes back and forth between the primary capacitor and the primary inductor. Energy is stored alternately as voltage across the capacitor or current through the inductor. Some of the energy from the capacitor also produces considerable heat and light in the spark gap. Energy dissipated in the spark gap is energy which is lost from the primary tank circuit, and it is this energy loss which causes the primary oscillation to decay relatively quickly with time.

The close proximity of the primary and secondary windings causes magnetic coupling between them. The high amplitude oscillating current flowing in the primary causes a similar oscillating current to be induced in the nearby secondary coil.

The self-capacitance of the secondary winding and the capacitance formed between the Toroid and ground result in another parallel resonant circuit being made with the secondary inductance. Its natural resonant frequency is determined by the values of the secondary inductance and its stray capacitances. The resonant frequency

of the primary circuit is deliberately chosen to be the same as the resonant frequency of the secondary circuit so that the secondary is excited by the oscillating magnetic field of the primary.



Energy is gradually transferred from the primary resonant circuit to the secondary resonant circuit. Over several cycles the amplitude of the primary oscillation decreases and the amplitude of the secondary oscillation increases. The decay of the primary oscillation is called "Primary Ring down" and the start of the secondary oscillation is called "Secondary Ring up". When the secondary voltage becomes high enough, the Toroid is unable to prevent breakout, and sparks are formed as the surrounding air breaks down.

Eventually all of the energy has been transferred to the secondary system and none is left in the primary circuit. This point is known as the "First primary notch" because the amplitude of the primary oscillation has fallen to zero. It is the first notch because the energy transfer process usually does not stop here. In an ideal system the spark gap would cease to conduct at this point, when all of the energy is trapped in the secondary circuit. Unfortunately, this rarely happens in practice.

If the spark gap continues to conduct after the first primary notch then energy begins to transfer from the secondary circuit back into the primary circuit. The secondary oscillation decays to zero and the primary amplitude increases again. When all of the energy has been transferred back to the primary circuit, the secondary amplitude drops to zero. This point is known as the "First secondary notch", because there is no energy left in the secondary at this time.

This energy transfer process can continue for several hundred microseconds. Energy sloshes between the primary and secondary resonant circuits resulting in their amplitudes increasing and decreasing with time. At the instants when all of the energy is in the secondary circuit, there is no energy in the primary system and a "Primary notch" occurs. When all of the energy is in the primary circuit, there is no energy in the secondary and a "Secondary notch" occurs.

Each time energy is transferred from one resonant circuit to the other, some energy is lost in either the primary spark gap, RF radiation or due to the formation of

sparks from the secondary. This means that the overall level of energy in the Tesla Coil system decays with time. Therefore both the primary and secondary amplitudes would eventually decay to zero.

After several transfers of energy between primary and secondary, the energy in the primary will become sufficiently low that the spark gap will cool. It will now stop conducting at a primary notch when the current is minimal. At this point any remaining energy is trapped in the secondary system, because the primary resonant circuit is effectively "broken" by the spark gap going open-circuit.

The energy left in the secondary circuit results in a damped oscillation which decays exponentially due to resistive losses and the energy dissipated in the secondary sparks.

Since the spark gap is now open-circuit the tank capacitor begins to charge again from the HV supply, and the whole process repeats again.

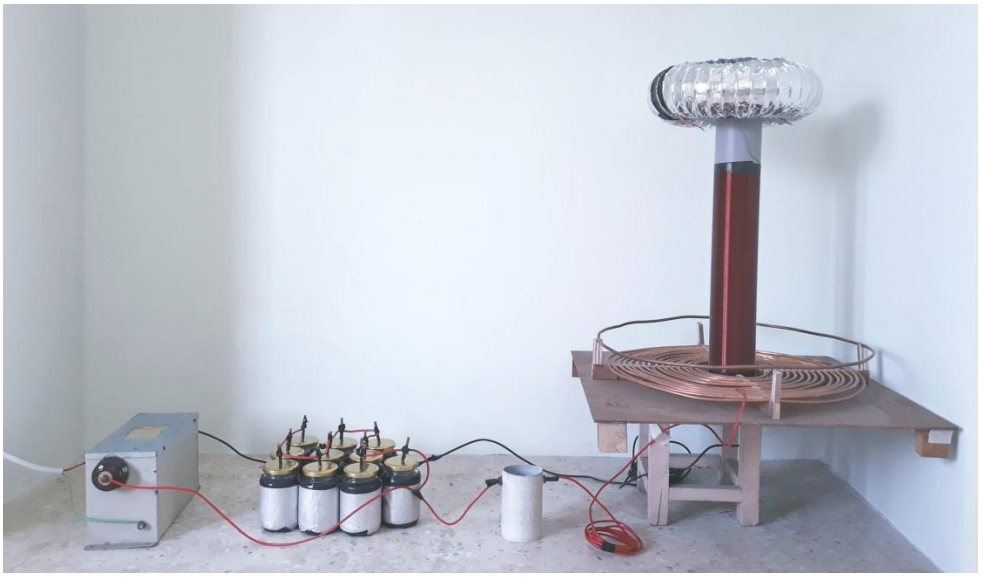
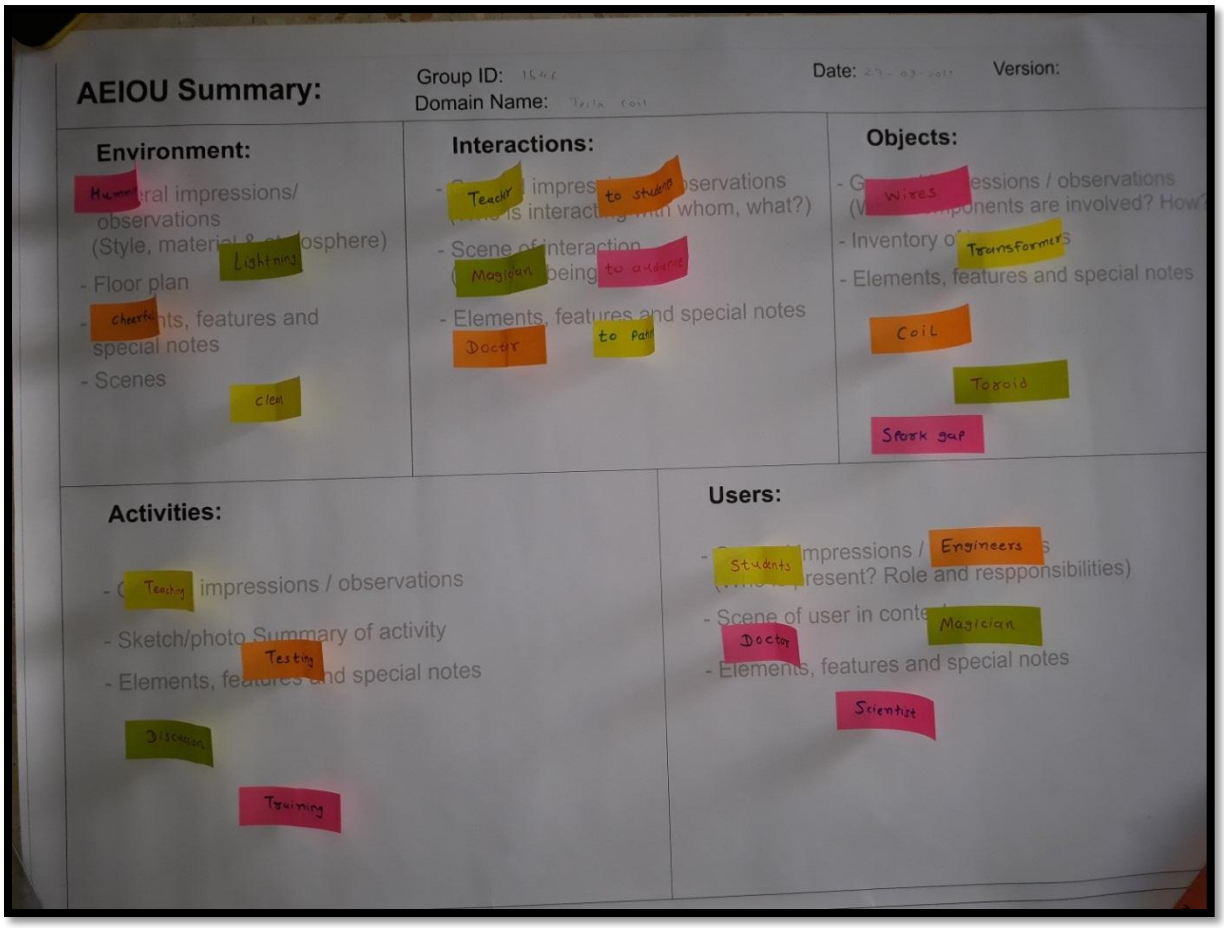


Fig. Actual model

5. AEIOU FRAMEWORK



Activities: Teaching, Testing, Discussion, Training

Environment: Lighting, Clean, Cheerful,

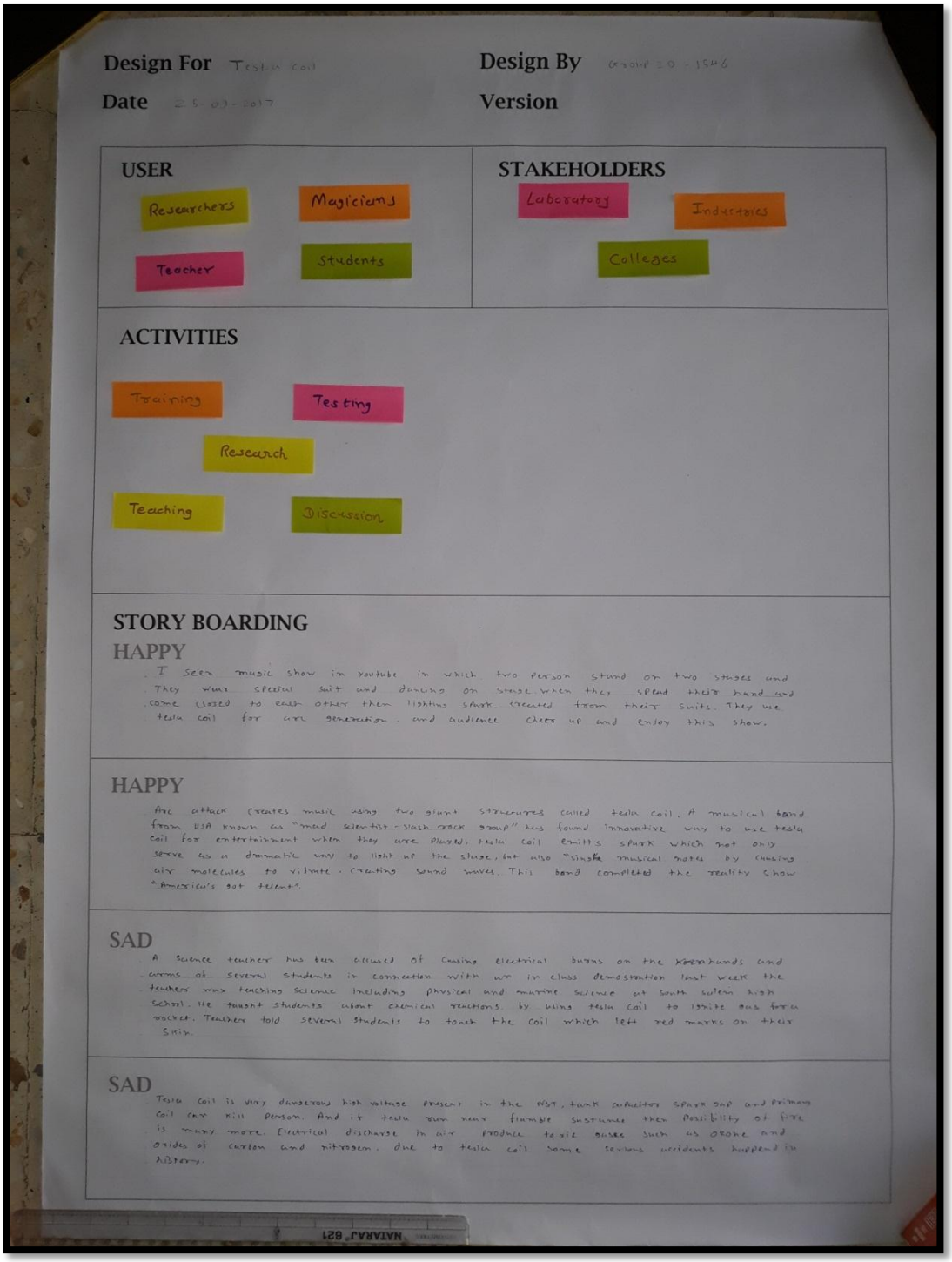
Interaction: Teacher to student,

Magician to audience,
Doctor to patient

Object: Wires, Transformers, Coil, Toroid, Spark gap

User: Student, Engineer, Magician, Scientist

6. Empathy mapping



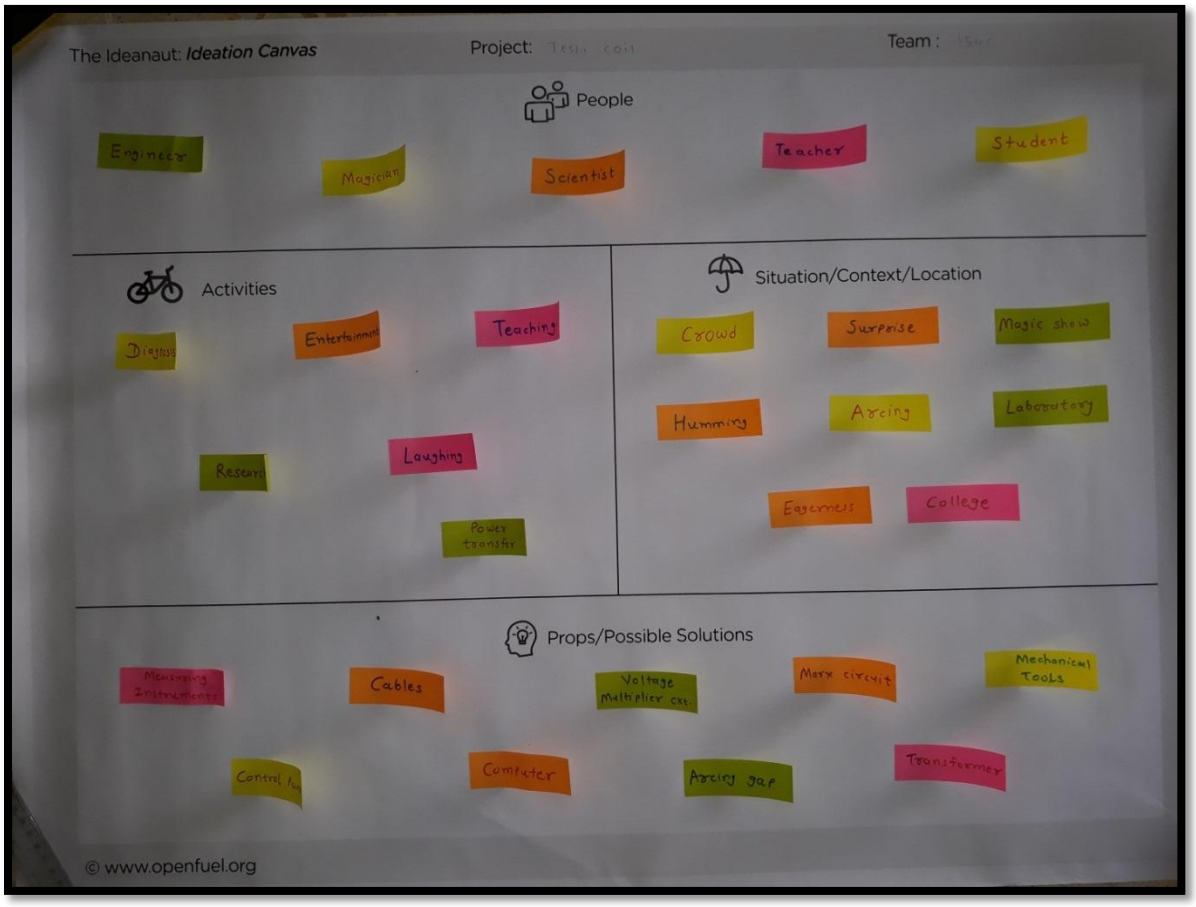
User: Researcher, Student, Teacher, Magician

Stakeholder: Laboratory, Collages, Magic Shows, Industries.

Activities: teaching, training, testing, research, discussion.

Story bonding: The story boarding is an activity where it is needed to incorporate emotions related with the activities and users, stakeholders identified. The story made up here tells about emotional attachments including this connected however, it is lacking of an on-hand experience of a user at present.

7. Ideation canvas



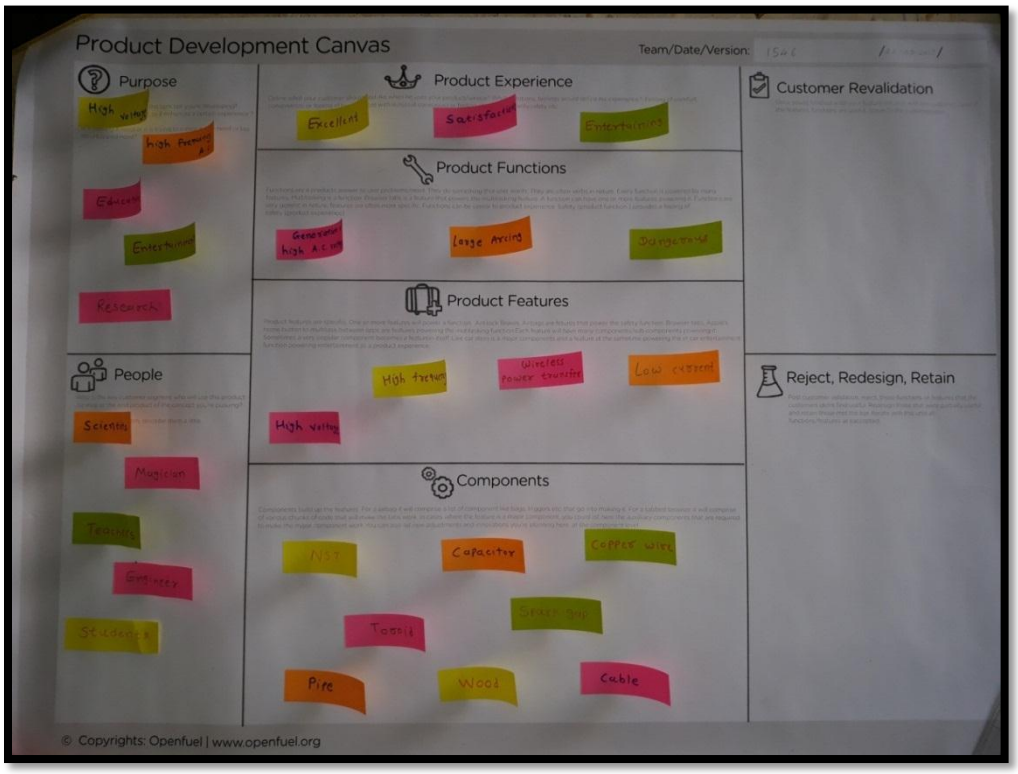
People: Engineer, Magician, Scientist, Teacher, Student.

Activities: Discussion, Teaching, Laughing, Research, Power Transfer, Entertainment.

Situation/context/location: Crowd Surprise Magic Show
Humming Arcing Laboratory
Eagerness Study Collage

Props/possible solutions: Cables Voltage Multiplier Circuit, Measuring Instrument, Marx Circuit, Mechanical Tool, Control Penal, Computer, Arcing Gap, Transformer.

8. Product Development Canvas



Purpose: High Voltage, High Frequency, Education, Entertainment, Research.

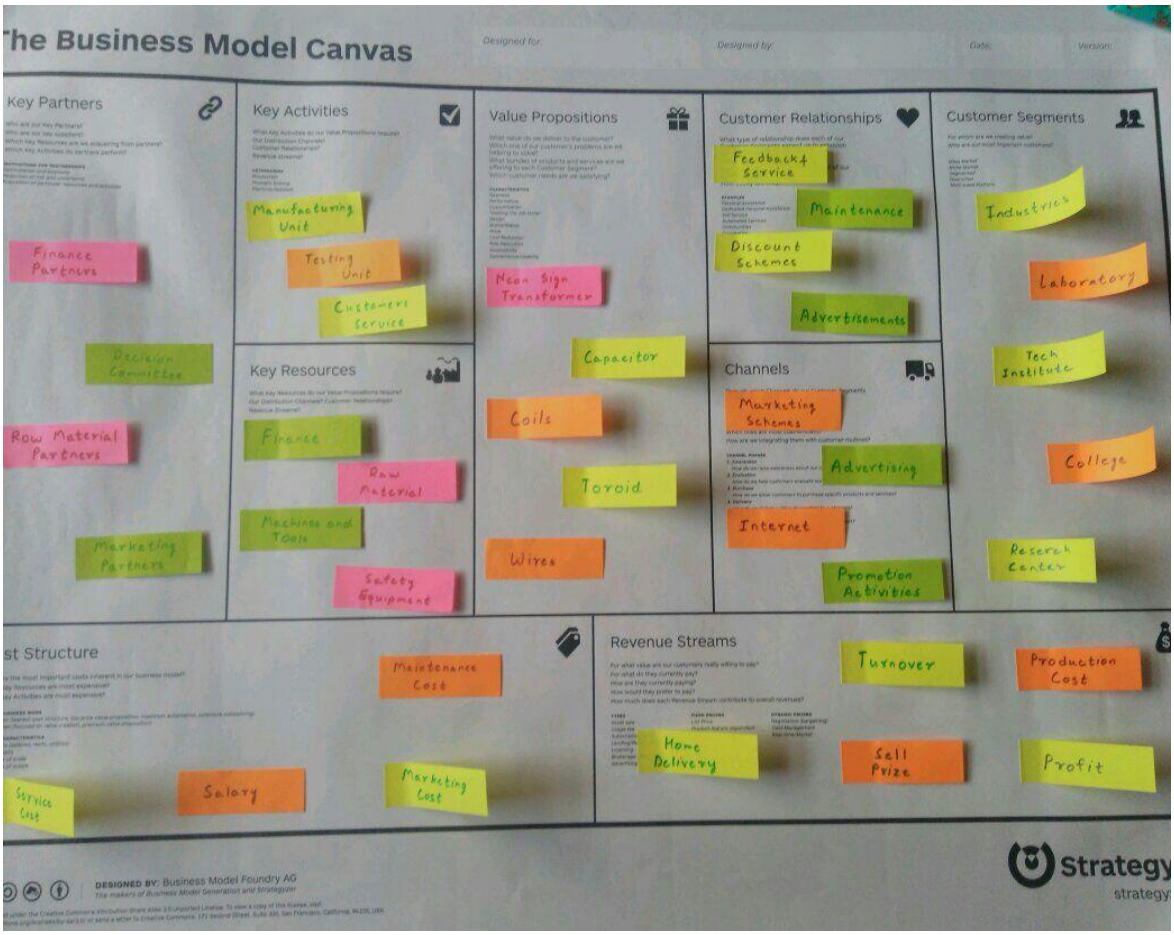
People: Scientist, Magician, Teacher, Engineer, Student.

Product experience: Excellent, Satisfaction, Entertainment.

Product Function: Generation of High AC Voltage, Large Arcing, Dangerous.
Product feature: High Voltage, High Frequency, Wireless Power Transfer, Low Current.

Components: NST, Capacitor, Copper Wire, Toroid, Spark Gap, Pipe, Wood, Cable.

9. Business Model Canvas



❖ KEY PARTNERS

➢ Finance Partners

Who provide financial support for investment, purchasing row materials, maintenance cost etc.

➢ Decision committee

It is Main Staff of Company Who Takes Major decisions about company.

➢ Row material partners

It is an industry or an organization who supplies row materials required for our product.

- **Marketing Partners**

This Partners plays main role to advertise the product to the consumers via different channels.

❖ KEY ACTIVITIES

- **Manufacturing Unit**

It is made of different departments which produce product by different steps

- **Testing Unit**

It is unit in which testing of product is done. It is helpful to maintain quality of product

- **Customer Service**

This department provides consumer satisfaction by giving them service like information about product.

- **R&D Department**

This dept. is helpful to develop product as per future technologies. It takes review of product to customers and upgrade product with new features.

❖ KEY RESOURCES

- **Finance**

It is main part through this we can buy row-materials, develop production department, factory, stationary, Machinery etc.

- **Raw-material**

Raw-material is a material which can be converted into product by process on it

- **Machines and Tools**

Machines and tools are used to process over row-material to convert it into useful product

- **Safety Equipment**

It must require in any company. It is like switch-gear for safety of instrument, fire safety, first aid box, etc.

❖ VALUE PROPOSITIONS

- **NEON SIGN TRANSFORMER**

It is used to produce high voltage supply .it prize is Rs.2500

- **CAPACITOR**

To store charge in it and trigger spark gap.it prize is Rs.500

- **COILS**

Primary coil and secondary coil cost is RS.900

- **TOROID**

It used to store charge and create high frequency arc. It cost is 300rs.

- **WIRES**

It is use to connect various parts of equipment.it cost is 300rs.

❖ CUSTOMER RELATIONSHIPS

It is all about how company maintains relationship with their customers by giving them facilities and services.

- **Feedback & Service**

It takes complains of customers and solve their problems.

- **Maintenance**

It is a facility provided by company to repair damaged or faulty product of customer in minimum time period.

- **Discount Schemes**

It is a policy of company to give discount or any schemes to attract customers or maintain their relationship with company

- **Advertisements**

It is a process to show feature and information about product to the customers. Via different channels like TV, radio, posters, internet etc.

❖ CHANNELS

- **Marketing Schemes**

If company provides any discount or schemes by this customers advertise other customers.

- **Advertising**

It is a channel which connects product to the consumers.

- **Internet**

It is most used media now days. Company can advertise their product information by internet media. Or providing information by their own website.

- **Promotion Activities**

Company can do promotion activities like social functions, social activities so consumers aware about company.

❖ CUSTOMER SEGMENTS

- **TECHNICAL INSTITUTES**

Our product is use in technical institutes to study tesla coil phenomena.

- **LABORATORY**

Our product is use in laboratory for research purpose.

- **INDUSTRIES**

Our product is helpful to industrialists for production of high voltage.

❖ COST STRUCTURE

- **Service Cost**

It is a cost for service the damaged product which is in warranty periods.

- **Salary**

It is cost to pay all the staff of company.

- **Maintenance cost**

It is a cost of maintenance of all the equipment and machinery of plant.

- **Marketing Cost**

It is cost used to marketing and advertisement of product.

❖ REVENUE STREAMS

- **Turnover**

Total Amount Company has per year.

- **Production Cost**

It is cost to produce the product. Like machinery working cost, raw-material cost etc.

- **Sell Prize**

It is a cost decided by company to sale a product including profit.

- **Credit Card/Online Payment**

It is facility provided by company in which customers can buy product or get information about prize of product through internet.

- **Home Delivery**

It is facility provided by company in which company deliver product to directly customer's home.

- **Profit**

It is amount which earn by company.

10. Applications:

- Wireless power transfer
- In medical devices like electrotherapy, pseudo medical devices
- In entertainment purpose, some magician use tesla coil to entertain audience
- Education purpose
- Vacuum system leak detector, tip of tesla coil placed on vacuum system and if tiny leak is there arc produced inside system.

11. Advantages:

- Absence of iron core in transformer so saving in cost and size
- Pure sine wave output
- Slow buildup of voltage over few cycle hence no damage due to switching surges

12. Drawback:

- Tuning proses is difficult and complex
- It is very dangerous
- Heating of spark gap so cooling arrangement required
- Due to corona discharge ozone produce so ventilation must be provided

13. Reference

- www.instructable.com
- www.teslacoildesign.com
- www.teslacoilcalculator.com
- Wikipedia