

# **Electric Shake Generator**

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## Introduction:

Electricity is an essential part of modern society. It is used to power devices that have become a vital part of modern life. With ever-growing demand for energy, new sources of energy must be discovered and expanded to provide for the growing demand. There are several ways electricity is generated. One of devices that are used to generate electricity is a generator, a device that converts mechanical energy obtained from an external source into electrical energy as the output (Diesel). The concepts discussed here are the principles used in devices seen on figure 1 such as “Shake Flashlights”, a device that uses no batteries or light bulb. The source of power in these devices is by shaking and provides an impressive output of 10 minutes of light on a light-emitting diode (LED). The wonder of these devices come from the renewable source of energy. Devices such as these demonstrate the ingenuity of the human mind to solve problems. The following experiment demonstrates the concept of Faraday's Principle of Magnetic Induction to generate enough current to power a LED. This demonstrates that energy could be generated from a clean, renewable source that does not pollute or damage the environment.



Figure 1 [google.com]

## Procedure:

The concept mentioned above will be used in the process of creating a generator. This generator, however, works in a similar way as a Shake Flashlight. The following generator is called “Shake-a-Gen”, a generator design adopted from Hare’s article on Journal of Physics Education (Hare).

### Materials:

1. Cylindrical-shaped plastic container
2. Enamel Coated copper wire: 30 Gauge 200ft or 60.96m long, 22 Gauge 75 ft or 22.86m long , thickness of the wire will determine power loss, but larger wires will create larger coil when the number of turns increases (Creative Science).
3. 5mm Light-Emitting Diode(LED): 1.8 Volt, 20mA
4. 6 Amazing Magnets: Diameter = .5625 in., Thickness = .125 in., Surface Gauss = 3030 or .303 Tesla each (Amazing Magnets)
5. Tape
6. Sand Paper
7. Optional: Foam cap for the container as a sound buffer

Step 1:

A cylindrical plastic container will be used to harbor the magnets for magnetic field in the device. This could be created using a sheet of plastic rolled into a cylinder. The length of this container plays many factors in the device. It will determine the length distance traveled by the magnet which could affect the rate of change of the magnetic field. This concept will be discussed further later on. On this experiment, 2 containers were used.

Step 2:

The enamel-coated wires are wind around the container. There are several ways this could be done. It is best to create a container for the wire to prevent the problem of “bird-nest” after many turns (Creative Science). The number of turns is an important data in the experiment, and will also affect the strength of the device.

Step 3:

After sanding both ends of the wire, connect them to the ends of the LEDs. This will complete the closed circuit.

Step 4:

Place 6 amazing magnets inside the container. The “magic” occurs when the device is shaken, and the LED should light up if enough current is generated by the device.

The images on figure 2 and 3 show the completed Shake-a-gen.



Figure 2 Prototype 1



Figure 3 Prototype II

## Theory:

The physics involved in the Shake-a-gen could be explained by Faraday's Law. Faraday's Law states that "any change in the magnetic environment of the coil of wire will cause a voltage (emf) to be "induced" in the coil (Hyper Physics). This change in magnetic environment could be achieved in several ways. The voltage could be generated from changing magnetic field strength, moving the magnets through the coil, moving into and out of the magnetic field, and rotating the coil relative to magnet (Hyper Physics). The Shake-a-gen works because of a changing magnetic field caused by the moving magnet induces a voltage into a coil of wire. A coil of wire surrounds a magnetic field and whenever the magnetic field changes, "a circular 'pressure' called Voltage appears" (Amasci). The rate of change of the magnetic field affects the strength of the voltage (Amasci). The effect of Electromagnetic Induction explains the current that is generated by the closed circuit. It is important to note that electrical energy is not created in the device. Diesel Supply explains that the device uses mechanical energy to force the movement of electric charges present in the wire of its windings through an external electrical current. This process is analogous to a water pump. The "water" in the device is the flow of electric charge which is measured by the output of electric current. "The movement of electrical charge creates a voltage difference between the two ends of the wire which causes electric charges to flow, generating electric current (Diesel) ". According to the Course Guide:

$$emf = - \frac{d}{dt} \Phi_m$$

Electromotive force (*emf*) is defined as the negative rate of change of the magnetic flux.

$$\Phi_m = N \int_S (\vec{B} \cdot \hat{n}) dA$$

$N$  = number of turns,  $B$  = Magnetic Field,  $A$  = Element area of the surface,  $\hat{n}$  = normal to the surface

After analyzing these equations, an equation can be derived for the Shake-a-gen device to determine the voltage output. The device has constant number of turns, constant area, and a changing magnetic field.

$$\Phi_m = N A B$$

$$emf = - \frac{d}{dt} \Phi_m = -N A \frac{\Delta B}{\Delta t}$$

The calculations of the voltage (*emf*) follows Faraday's law, as explained on figure 4.

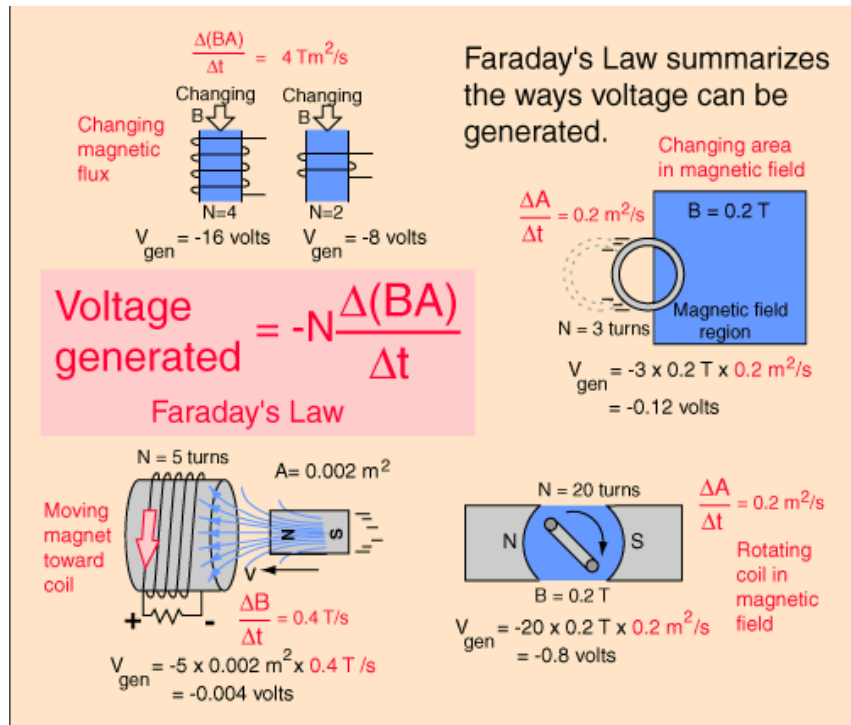


Figure 4 Variation of Faraday's Law. Hyper Physics

According to figure 4, the strength of the emf is related to the number of turns, the area of the surface, and the rate of the change of the magnetic field. The device allows the magnet to move into and out of the coil in a way that the direction could be changed in each half revolution. The negative in the equation could be explained by Lenz Law, which states that the direction or "sense" of the voltage generated is such that any resulting current produces a magnetic field opposing the change in magnetic field which created it (Hyper Physics). From this analysis, the device could be categorized as Alternating Current (AC) Generator. This means that the sign on both wires changes as the magnets travel from one end to the other. As a result, the AC Generator could power an LED without worrying about wire connections.

## Result:

After understanding the physics involved in the device, several prototypes were made to generate enough voltage to power an LED. The first prototype on figure 2 has the following properties.

### Prototype I:

Magnetic Field (B):  $6 \text{ Magnets} \times .303T = 1.818 T$

Length of Coil (L) – Length that the coil is distributed on the device; determines the travel distance of the magnets

Area = circular area of the cylinder

$V_{MAX}$  = Maximum Voltage Output

$I_{MAX}$  = Maximum Current Output

Radius	L	N	$B_{MAX}$	Area	$V_{MAX}$	$I_{MAX}$
.014288m	.0762m	130	1.818 T	.000641m <sup>2</sup>	.22V	.293A

Note: The maximum number of turns was used for greater voltage output.

Measuring the rate of change of the magnetic field of the device during testing could cause several errors. The values measured above shows the peak values of the device shaken by one person. The speed of shaking varies, but the max values are recorded. From the above table, the rate of change could be derived.

$$\left| \frac{\Delta B}{\Delta t} \right| = \left| -\frac{emf}{NA} \right| = \frac{.22V}{130 * .000641m^2} = 2.64 \frac{T}{s}$$

The maximum magnetic field at one time is 1.818 T. The frequency is then:

$$2.64 \frac{T}{s} \div 1.818T = 1.45215 s^{-1}$$

Based on the recorded values, this prototype was not able to output enough voltage to power the LED. Further experiment with LED attached to the device showed that the device was not powerful enough to power the LED. One major problem with this prototype is the low frequency. The low rate of change of the magnetic field caused the device to output very low voltage.

## Prototype II:

Prototype II, figure 3, improves the design of the previous design.

Magnetic Field (B):  $6 \text{ Magnets} \times .303T = 1.818 T$

Length of Coil (L) – Length that the coil is distributed on the device ; determines the travel distance of the magnets

Area = circular area of the cylinder

$V_{MAX}$  = Maximum Voltage Output

$I_{MAX}$  = Maximum Current Output

Radius	L	N	$B_{MAX}$	Area	$V_{MAX}$	$I_{MAX}$
.0127m	.01905	220	1.818 T	.000507m <sup>2</sup>	1.5V	.15A

Note: The maximum number of turns was used for greater voltage output.

This prototype improved upon the problems that were discovered on the previous prototype. Some values to note are the changes in the number of turns and the length of the coil. As mentioned previously, the number of turns is related to the strength of the voltage while the length of the coil could affect the rate of change of the magnetic field. Once again, the maximum rate of change must be derived because of varying speeds.

$$\left| \frac{\Delta B}{\Delta t} \right| = \left| -\frac{emf}{NA} \right| = \frac{1.5V}{220 * .000507m^2} = 13.4481 \frac{T}{s}$$

The maximum magnetic field at one time is 1.818 T. The frequency is then:

$$13.4481 \frac{T}{s} \div 1.818T = 7.39719 s^{-1}$$

The second prototype showed greater potential than its predecessor. The recorded values above show that greater rate of change of magnetic field could be achieved with the device. This resulted in greater output voltage. After attaching an LED to prototype II, a bright red light was observed. The experiment was successful.

## Conclusion:

Devices such as the “Shake-a-gen” sparked from the minds of humans in pursuit of greater knowledge about the unknown universe. The experiment has demonstrated that with creativity and ingenuity, humans could manipulate forces around them to make lives easier. One such device is Shake Flash flights which could be a savior during blackouts or storms. The human potential for knowledge has allowed humans to flourish on Earth. It could also be used to save humans from the mistakes of pollution and overuse of resources. This experiment hopes that a spark of bright red could inspire thinkers to achieve their potential.

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