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ORBUS

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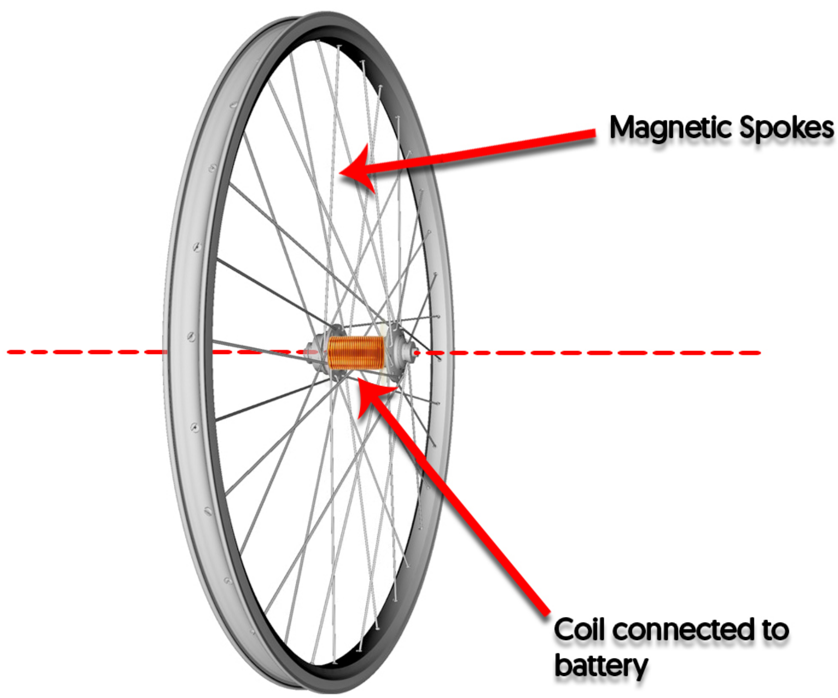
Contents

Part I
Introduction

Basic Principle: Conversion of rotational kinetic energy in a bicycle wheel into usable electrical energy by implementing the laws of electromagnetic induction.

Idea:



The basic idea is to use the rotational kinetic energy to create magnetic flux which induces an electric current in the coil as the wheel rotates. This, in turn, can be stored and used later as an energy source to temporarily power the bike to journey rougher terrains more easily. For example, this could be used to power the bike when cycling uphill.

This not only promotes the use of clean and green energy but also encourages people to cycle more often. People choose their cars over other modes like the bicycle due to the amount of effort required. This would reduce the amount of effort and thereby increase the popularity of the bicycle. Furthermore, the amount of cars on the road will gradually reduce as people use bicycles more often.

Part II
Mathematics

1 Magnetic Flux

1.1 Fundamental Concepts

The law of physics describing the process of electromagnetic induction is known as Faraday's law of induction and the most widespread version of this law states that the induced electromotive force in any closed circuit is equal to the rate of change of the magnetic flux enclosed by the circuit. Or mathematically,

$$\varepsilon = -\frac{d\Phi_B}{dt},$$

where ε is the electromotive force (EMF) and Φ_B is the magnetic flux. The direction of the electromotive force is given by Lenz's law. This version of Faraday's law strictly holds only when the closed circuit is a loop of infinitely thin wire, and is invalid in some other circumstances. A different version, the Maxwell–Faraday equation, is valid in all circumstances.

For a tightly wound coil of wire, composed of N identical turns, each with the same magnetic flux going through them, the resulting EMF is given by

$$\varepsilon = -N\frac{d\Phi_B}{dt}$$

Faraday's law of induction makes use of the magnetic flux Φ_B through a hypothetical surface Σ whose boundary is a wire loop. Since the wire loop may be moving, we write $\Sigma(t)$ for the surface. The magnetic flux is defined by a surface integral:

$$\Phi_B = \iint_{\Sigma(t)} \mathbf{B}(\mathbf{r}, t) \cdot d\mathbf{A}$$

where $d\mathbf{A}$ is an element of surface area of the moving surface $\Sigma(t)$, B is the magnetic field, and $\mathbf{B} \cdot d\mathbf{A}$ is a vector dot product (the infinitesimal amount of magnetic flux). In more visual terms, the magnetic flux through the wire loop is proportional to the number of magnetic flux lines that pass through the loop.

When the flux changes—because $\mathbf{B}$ changes, or because the wire loop is moved or deformed, or both—Faraday's law of induction says that the wire loop acquires an EMF, ε, defined as the energy available from a unit charge that has travelled once around the wire loop. Equivalently, it is the voltage that would be measured by cutting the wire to create an open circuit, and attaching a voltmeter to the leads.

According to the Lorentz force law (in SI units),

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

the EMF on a wire loop is:

$$\varepsilon = \frac{1}{q} \oint_{wire} \mathbf{F} \cdot dl$$

$$\Rightarrow \varepsilon = \oint_{wire} (\mathbf{E} + \mathbf{v} \times \mathbf{B}) \cdot dl$$

1.2 Maxwell-Faraday Equation

The Maxwell–Faraday equation is a generalisation of Faraday's law that states that a time-varying magnetic field is always accompanied by a spatially-varying, non-conservative electric field, and vice versa. The Maxwell–Faraday equation is

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

where $\nabla\times$ is the curl operator and again $\mathbf{E}(\mathbf{r}, t)$ is the electric field and $\mathbf{B}(\mathbf{r}, t)$ is the magnetic field. These fields can generally be functions of position $\mathbf{r}$ and time t.

The Maxwell–Faraday equation is one of the four Maxwell's equations, and therefore plays a fundamental role in the theory of classical electromagnetism. It can also be written in an integral form by the Kelvin-Stokes theorem:

$$\oint_{\partial\Sigma} \mathbf{E} \cdot dl = -\int_{\Sigma} \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{A}$$

where:

Σ is a surface bounded by the closed contour $\partial\Sigma$,

$\mathbf{E}$ is the electric field, $\mathbf{B}$ is the magnetic field.

dl is an infinitesimal vector element of the contour $\partial\Sigma$,

$d\mathbf{A}$ is an infinitesimal vector element of surface Σ. If its direction is orthogonal to that surface patch, the magnitude is the area of an infinitesimal patch of surface.

We will use the above equations to compute the EMF generated when the wheel is in motion. And with this we can also derive the equations that will tell us the electricity induced in the coil and in turn compute the power generated by the wheel.

2 Induced Current

2.1 Ampère's Law

Ampère's law relates magnetic fields to electric currents that produce them. Ampère's law determines the magnetic field associated with a given current, or the current associated with a given magnetic field, provided that the electric field does not change over time.

Ampère's circuital law is now known to be a correct law of physics in a magnetostatic situation: The system is static except possibly for continuous steady currents within closed loops. In all other cases the law is incorrect unless Maxwell's correction is included (see below).

The mathematical statement of the law is a relation between the total amount of magnetic field around some path (line integral) due to the current which passes through that enclosed path (surface integral). It can be written in a number of forms.

In terms of total current, which includes both free and bound current, the line integral of the magnetic **B**-field (in tesla, T) around closed curve C is proportional to the total current Ienc passing through a surface S (enclosed by C):

$$\oint_C \mathbf{B}\cdot dl = \mu_0 \iint_S \mathbf{J}\cdot d\mathbf{S} = \mu_0 I_{enc}$$

where **J** is the total current density (measured in ampere per square metre, Am^{-2})

This equation can be extended to what is known as the Maxwell–Ampère equation which is given by:

$$\oint_C \mathbf{B}\cdot dl = \iint_S \left(\mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial}{\partial t}\mathbf{E}\right) \cdot d\mathbf{S}$$

$$\Rightarrow \iint_S \left(\mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial}{\partial t}\mathbf{E}\right) \cdot d\mathbf{S} = \mu_0 I_{enc}$$

$$\Rightarrow I_{enc} = \iint_S \left(\mathbf{J} + \varepsilon_0 \frac{\partial}{\partial t}\mathbf{E}\right) \cdot d\mathbf{S}$$

where μ_0 and ε_0 are permeability and permittivity of free space constants repsectively.

2.2 Lorentz Force

The electromagnetic force $\mathbf{F}$ on a test charge at a given point and time is a certain function of its charge q and velocity $\mathbf{v}$, which can be parameterized by exactly two vectors $\mathbf{E}$ and $\mathbf{B}$, in the functional form:

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B})$$

When a wire carrying an electric current is placed in a magnetic field, each of the moving charges, which comprise the current, experiences the Lorentz force, and together they can create a macroscopic force on the wire (sometimes called the Laplace force). By combining the Lorentz force law above with the definition of electric current, the following equation results, in the case of a straight, stationary wire:

$$\mathbf{F} = Il \times \mathbf{B}$$

where l is a vector whose magnitude is the length of wire, and whose direction is along the wire, aligned with the direction of conventional current flow I.

If the wire is not straight but curved, the force on it can be computed by applying this formula to each infinitesimal segment of wire dℓ, then adding up all these forces by integration. Formally, the net force on a stationary, rigid wire carrying a steady current I is

$$\mathbf{F} = I \int dl \times \mathbf{B}$$

From Faraday's law of induction (that is valid for a moving wire, for instance in a motor) and the Maxwell Equations, the Lorentz Force can be deduced. The reverse is also true, the Lorentz force and the Maxwell Equations can be used to derive the Faraday Law.

Let $\Sigma(t)$ be the moving wire, moving together without rotation and with constant velocity v and $\Sigma(t)$ be the internal surface of the wire. The EMF around the closed path $\partial\Sigma(t)$ is given by:

$$\varepsilon = \oint_{\partial\Sigma(t)} dl \cdot \mathbf{F}/q$$

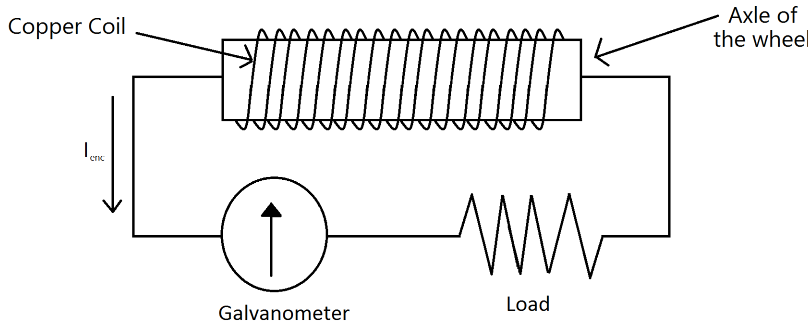
where

$$\mathbf{E} = \mathbf{F}/q$$

We now have all the equations and mathematics necessary to compute various components required to know to develop the product. Now we will move on the actual circuit development.

3 Coil Circuit

The basic idea is to use the magnetic field generated by the spokes and induce a current in the coil on the axle. This current is then stored into a battery or a load of some sort and used later for other purposes. The circuit for the coil is shown below:



Here is a sample model of how the actual wheel is going to look from a three-dimensional perspective:

The polarized or magnetized spokes will create a magnetic field that the coil can cut through to induce a current. In the above figure, the connection to the battery is not shown and it is being viewed from the perspective of one side of the wheel. Some of the various components we need to compute is the total magnetic flux in the wheel, the current is being produced per rotation and the amount of current that is actually stored for useful work. The previously explained mathematics and theorems will aid us in calculating these variables.

Part III
Development

4 Experiment #1 : Polarizing Spokes

One of the primary components of the product is the magnetized spokes present o the wheel. This is a absolutely necessary element as the spokes are going to provide the magnetic field and the magnetci flux with which the coil is going to use to induce a current. An article on the Princeton University website has provided a few effective ways to permanently magnetize or polarize metal.

Magnetizing Steel Bars With Magnets:

Method 1: Simple touch – rub the north pole of a magnet from the middle of the bar to one end, and the south pole from the middle to the opposite end an equal number of times.

Method 2: Double touch – take two magnets, touch the south pole of one and the north pole of the other to the center of the bar, and draw them off to the ends a number of times.

Method 3: Touch in a circuit – form a circuit (square) with four bars and move a horseshoe magnet over it. While one source says it should be moved "backwards and forwards", the rest agree that the magnet should only be moved in one direction, then slid off onto a piece of soft iron. Two bar magnets can be substituted for the horseshoe magnet, and a group of six magnets can be more strongly magnetized by using two as a horseshoe and then substituting them with two from the circuit and so on.

Magnetizing Steel Bars Without Magnets:

Method 1: Strike a bar, either held vertically or pointed north, (some sources say soft iron and others say hardened iron or steel) several times on one end with a hammer.

Method 2: Hang a bar vertically for a lengthy but unspecified amount of time (probably a few days to a week or so). These magnets can then be used to induce magnetism by the methods given above.

Tip: Use a natural loadstone.

5 Experiment #2: Current Induction

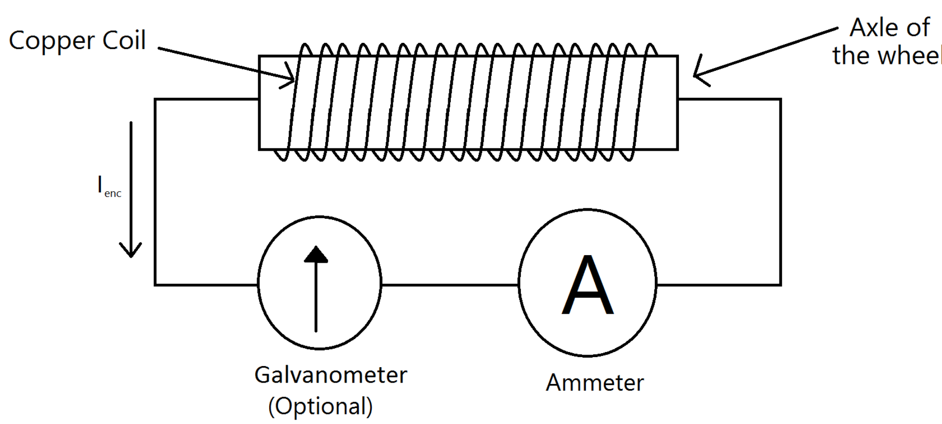
Once the spokes have been magnetized, we can now test for current induction. We simply wound a coil around the axle of the wheel and check the induced current as the wheel is rotating.

Apparatus:

1. A bicycle wheel
2. Magnetized spokes
3. Copper Coil
4. Ammeter
5. Galvanometer (Optional)

Procedure:

If not already completed, attatch the magnetic spokes to the bicycle wheel. Then we wound the copper coil around the axle of the wheel as shown in the first diagram. Then assemble the remaining components like the circuit diagram shown below. This circuit diagram is similar to the prototype circuit except the ammeter is being attached instead of a load to measure the current induced. The galvanometer can be attached to circuit to check for weaker currents if required. Finally, simply rotate the wheel and check the readings on the ammeter and galvanometer (if attatched). Repeat this process with various rotation speeds and collect the data and compute the results.



The results of this experiment will eventually lead us to the next question in the process, how much of the current induced can be stored? The documentation for this experiment will be more consummate and comprehensive when actually conducting the experiment. Furthermore, once the inital results are adequate for progress we can start developing the technology for a gyroscope based power regulation and other technological advances. But for the inital basic prototype, the main goal is to be able to produce and efficiently store electricity.

Part IV
Conclusion

The initial product will not be as efficient as possible but as technology develops, so will this. And this could potentially revolutionize transportation in the long run. Furthermore, this also promotes a lot of good things that benefit the environment namely clean energy and reduced pollution. This also has the possibility of increasing the popularity of the bicycle industry and could completely change the transportation industry as we know it.

Part V
Bibliography

Landau, L. D., Lifshit M., & Pitaevskiĭ, L. P. (1984). Electrodynamics of continuous media; Volume 8 Course of Theoretical Physics (Second ed.). Oxford: Butterworth-Heinemann. p. 63 (49 pp. 205–207 in 1960 edition). ISBN 0-7506-2634-8.

Roger F Harrington (2003). Introduction to electromagnetic engineering. Mineola, New York: Dover Publications. p. 56. ISBN 0-486-43241-6. Jump up ^ M N O Sadiku (2007). Elements of elctromagnetics (Fourth ed.). NY/Oxford: Oxford University Press. p. 391. ISBN 0-19-530048-3.

M N O Sadiku (2007). Elements of elctromagnetics (Fourth ed.). NY/Oxford: Oxford University Press. p. 391. ISBN 0-19-530048-3.

Heinz E Knoepfel (2000). Magnetic Fields: A comprehensive theoretical treatise for practical use. Wiley. p. 4. ISBN 0-471-32205-9.

George E. Owen (2003). Electromagnetic Theory (Reprint of 1963 ed.). Courier-Dover Publications. p. 213. ISBN 0-486-42830-3.

Stuart B. Palmer & Mircea S. Rogalski (2006). Advanced University Physics. CRC Press. p. 251. ISBN 1-58488-511-4.

https://www.princeton.edu/ssp/joseph-henry-project/permanent-magnet/

http://www.wikihow.com/Magnetize-Steel (For images)