

Generating Magnetic Field by Electric Current 2

# Ampère's circuital law

**NaRiKa** Corporation

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## 1. Learning Outcome

While experiments on Electric Current and Magnetic Field are normally done by using dry cell batteries or electric power-supply units, we are going to use the hand-held generator “(Narika) Genecon V3” in this Unit. In case of using dry cell batteries or electric power-supply units, students can merely turn on a circuit and observe the electrical phenomena. However, they cannot only observe the experiment in operation, but also control it as they wish by using the hand-held generator Genecon V3, which helps students’ better understanding of experiments objectives through hands-on experience involving them.

In this Unit, we will focus on how to make students better/deeper understand phenomena related to Magnetic Field and Electric Current through in-depth students-centered hands-on experiments about the Ampere's law.

## 2. Historical Background

Up until W. Gilbert (UK) reported his study in 1600, no major study report had been made public for 2200 years ever since Thales of Miletus of ancient Greece recognized the electrostatic phenomenon of attracting dust or feather when rubbing amber with fur in 600 B.C. In 1800, which is 200 years after the Gilbert’s report, A. Volta (Italy) invented battery (known as the “Voltaic Cell”), which means it took 200 years for the transition from the study on static electricity to dynamic electricity.

Using Voltaic Cell as a power source, notable study was made by H. C. Oersted (Denmark) when he discovered that compass needle should

deflect near a cable carrying current, which was made public in publication named “Interaction of Current and Magnetism”, on

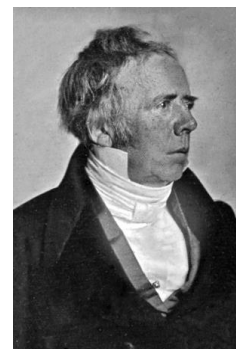
September 1<sup>st</sup>, 1820, at the conference of Paris Academy of Sciences. Soon after being deeply impressed with Oersted’s report, A. M. Ampere (France) started his study and soon made public his theory of Electricity and Magnetism including previously discovered electromagnetic phenomena.



A. M. Ampere

[http://en.wikipedia.org/wiki/File:](http://en.wikipedia.org/wiki/File:Ampere_Andre_1825.jpg)

Ampere\_Andre\_1825.jpg



Hans Christian  
Ørsted

[http://en.wikipedia.org/wiki/](http://en.wikipedia.org/wiki/Hans_Christian_Ørsted)

Hans\_Christian\_Ørsted

[1.] Ampere's Right Hand Law (or Right-hand Rule):

Ampere discovered that magnetic field is spirally generated around the

electric current flowing in the direction toward which “Right Screw” is tightened.

[2.] Using two of conductive wires carrying electric current to observe magnetic action in between, he examined that repulsive magnetic action occurs when the wires carry the current toward the opposite direction, while attractive magnetic action occur when the wires carry the current toward the same direction.

The 9<sup>th</sup> General Conference on Weights and Measures held in 1948 adopted “ampere” as a unit of electric current. It is the steady current that when flowing in straight parallel wires of infinite length and negligible cross section, separated by a distance of one meter in free space, produces a force between the wires of  $2 \times 10^{-7}$  newtons per meter of length”. The 10<sup>th</sup> General Conference on Weights and Measures held in 1954 formally adopted ampere as the basic unit for electrical current. Thus, the study done by A.M. Ampere is inevitable not only for electromagnetic but also for our daily lives.

### 3. Introduction of Equipment for Experiments

#### [1] Genecon V3:

Genecon V3 is a product name of the hand-held power generator manufactured by Narika Corporation. Up to 3V DC electricity can be generated just by turning the handle, hence the user realizes how he/she is generating electric power in person. Since Genecon V3 generates only up to 3V, it highly unlikely damage accessories used for experiment at schools like miniature bulbs, LED lamps. electric musical (melody) boxes, and others. Also, it replaces dry cell batteries used for experiment like lighting miniature bulbs/LEDs, electrically heated wire, or others.



Genecon V3  
(Narika B10-2634)

Mechanism of Genecon V3 is quite simple, consisting of the motor inside for generating power, which should leave almost no room for students to misunderstand the relationship/function of internal motor, gears, shafts and handle due to its perfect visibility through the transparent body. For teachers, Genecon V3 significantly helps their explanation to students regarding the fact that motor and generator are identical.

#### [2] Ampere Apparatus (Observation Apparatus for Magnetic field around Current):

Experimental apparatus used for confirming Ampere's Right-handed Grip Rule normally requires large current of 30A, however power supply unit for such large current is generally not available in most of schools. Furthermore, due to its high risk, usage of such apparatus is limited to the demonstration by teachers.

The “Ampere Apparatus” is safely used with the maximum current of 3A for the observation of magnetic field spirally generated around (conductive) wire. Even students can safely use the apps. One set of the apps includes the combination of two types (U-shaped and Solenoid) of observation units. In this Unit, we are going to observe how magnetic field is generated by using DC power supply unit (3A) or Genecon V3 as the power source.



Ampere Apparatus

(Narika B10-4753)

**[3] Mag Chip:**

Originally developed by Narika as “micro” and “powdery” wires for magnetic field observation. Iron powder or iron sand is normally used in schools for observing magnetic field despite its user-unfriendliness in that experimental equipment and lab bench get easily dirty, which requires quite time-consuming cleanup afterwards. Mag Chips are tiny fragments of galvanized iron wire divided into approx. 2 mm long chips, of which feature is resistance to corrosion and easy collection after use.



“Mag Chip”

(Narika B10-3720)

## 4. Ampère's circuital law

### 1. Formation of Electric Field by Electric Current ~A. M. Ampere~

On 1st of September 1820 in French Academy of Science in Paris, Danish H. C. Oersted announced that electric current generates magnetic field. A. M. Ampere was deeply impressed by this announcement and immediately started his own research about electric current and magnetic field. Then, in the same year on 19th of September, he presented in French Academy of Science in Paris following theory related to the electric current and magnetic field.

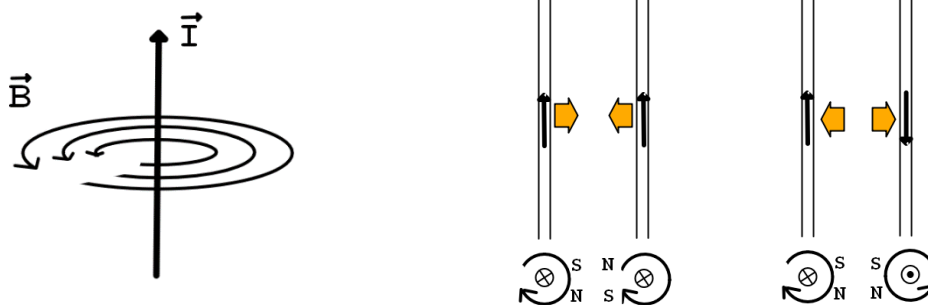


[http://en.wikipedia.org/wiki/File:Ampere\\_Andre\\_1825.jpg](http://en.wikipedia.org/wiki/File:Ampere_Andre_1825.jpg)

[1.] Ampere discovered that magnetic field is spirally generated around the electric current flowing in the direction toward which "Right Screw" is tightened. In other words, magnetic field is generated around current flow. This is called Right-hand rule (or Right-hand grip rule) (see the figures below).

[2.] By using two conductive wires carrying electric current to observe magnetic action between them, he examined repulsive magnetic action occurs when the wires carry the current toward opposite direction, while attractive magnetic action occurs when the wires carry the current toward same direction (see the figures below).

By this theory it became possible to successfully explain previously discovered electromagnetism phenomenon.



Right-hand rule expressed in numerical way looks like this:

$$2\pi rH = I \quad H = \frac{I}{2\pi r}$$

I: Current, r: Distance between two current flows, H: Strength of the magnetic field

## 2. Experiment on Right-hand Rule

### 1. Purpose of this experiment:

In this Unit, we will confirm Ampere's right-hand rule. We will observe the magnetic field around the (single) wire carrying electric current and then around the solenoidal wire. After that, compare the observations.

### 2. What to prepare:

*Genecon V3:	1 pc	(Narika B10-2634)
*Power supply unit (DC20V, 5A):	1 pc	(School equipment)
*Ampere Apparatus (Single wire):	1 pc	(Narika B10-4753)
*Ampere Apparatus (Solenoidal wire):	1 pc	(Narika B10-4753)
*Mag Chips (for observing magnetic field):	Small amount	(Narika B10-3720)
*Cable with clips (red and black):	1 pc	(Narika B10-6503)
*Small compass:	10 pcs	(Narika B10-3589-02)

### 3. Experiment 1: Experiment using GeneconV3

- 1) Make pairs.
- 2) Remove the plastic covers from terminals (red and black) on observation unit with single wire.
- 3) Connect the cable with clips (red and black) of Genecon V3 to the metal part of the terminals (red and black). See Fig.1.
- 4) Pour Mag Chips to the observation unit (front part) and spread them evenly on the bottom.

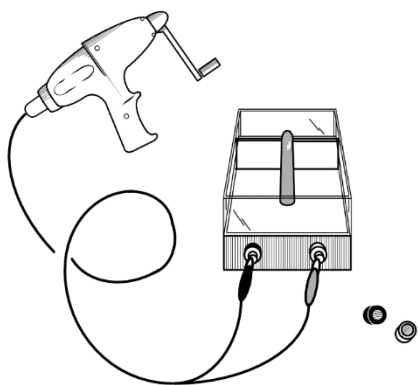


Fig.1



Fig.2.

- 5) One person will start turning the handle of Genecon V3 as fast as possible.
- 6) The other person will start tapping the side of the Apparatus (single wire) by his/her finger. See Fig.3.
- 7) Make sure whether you can see the electric field in the observation unit of Ampere Apparatus (single wire).
- 8) In the case that you cannot see electric field, repeat steps 5-7 again.
- 9) Do in the same way steps 1-8, this time with observation unit of

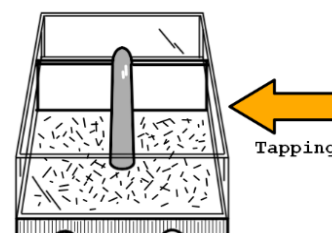
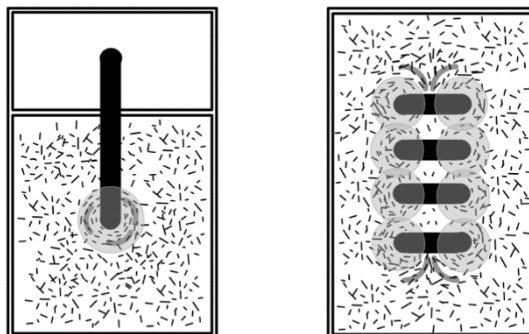


Fig.3.

Ampere Apparatus (Solenoid).

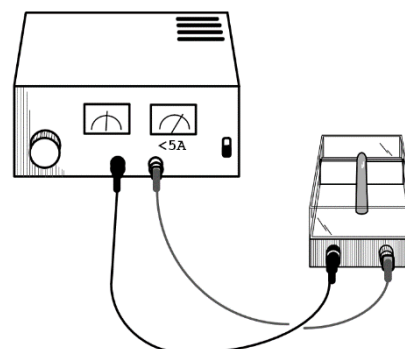
10) Draw the shape (pattern) of the electric fields in the figures below.



#### 4. Experiment 2: Experiment using Power Supply Unit

- 1) Connect red and black terminal of Power supply unit with Ampere Apparatus (single wire) by two cables.
- 2) Pour Mag Chips to Ampere Apparatus (single wire) observation box (front part) and spread them evenly on the bottom. See Fig.2.
- 3) Switch on the Power supply unit and set current value to 3 A.

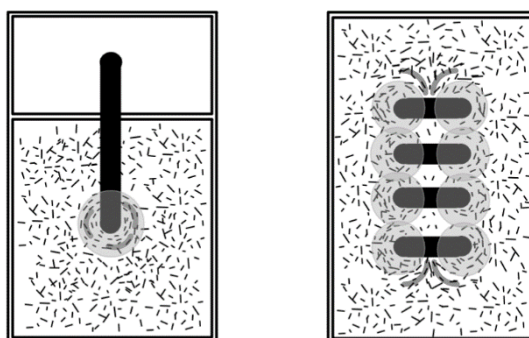
**Attention: If Power supply unit is on for more than 1 minute, connecting cables will become hot. Therefore, be careful not to melt down the cable jacket.**



- 4) One person will start taping the side of the Apparatus (single wire) by his/her finger. See Fig.3.
- 5) Make sure whether you can see in the observation unit of Ampere Apparatus (single wire) electric field.
- 6) After you could see the magnetic field, switch off the Power supply unit.

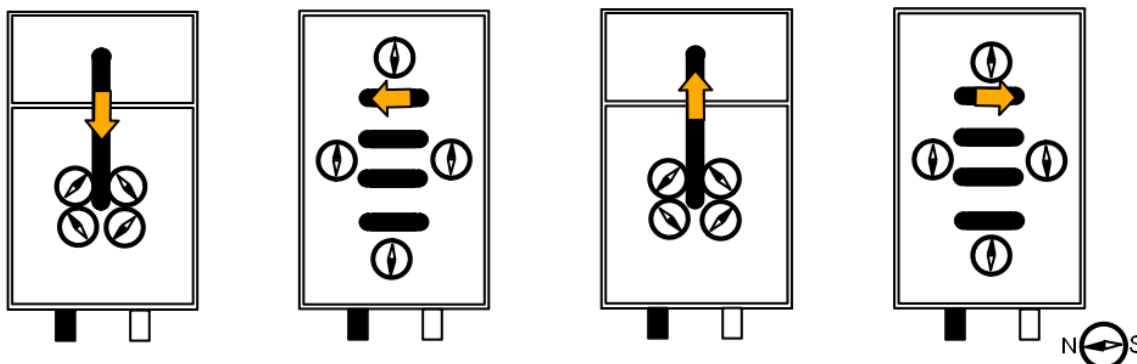
**Caution: Touch the cable from power supply unit by your finger, if the cable is hot, please wait for a while before you proceed to next step.**

7) Do in the same way steps 1-6, this time with Ampere Apparatus (Solenoid).



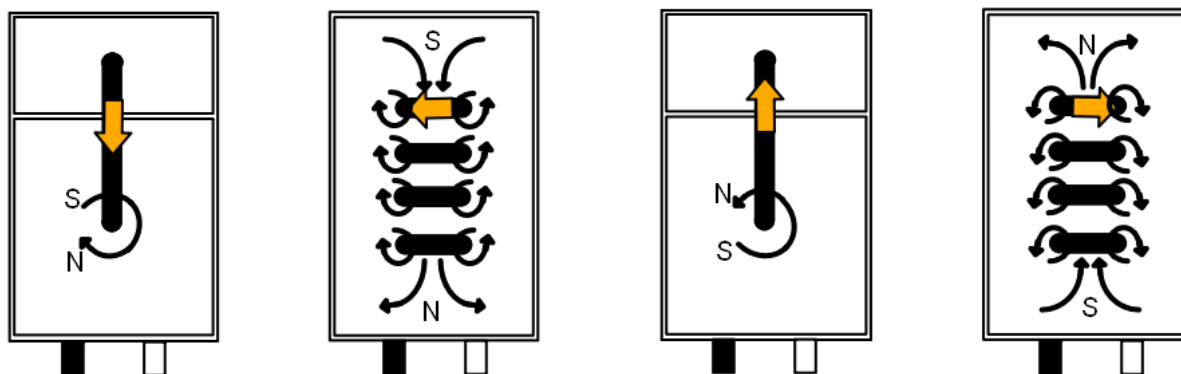
### 5. Experiment 3: Experiment using Magnetic Compass

- 1) Connect red and black terminal of Ampere Apparatus (single wire) by two cables either with Genecon V3 or Power supply unit.
- 2) Place several compasses into the observation unit (front part) of Ampere Apparatus (single wire).
- 3) Perform experiment according to the procedure of experiment 1 (with Genecon V3) or experiment 2 (with Power supply unit).
- 4) Draw deflection of the direction of compass needle below.



### 3. Summary of Experiment

Please draw below and explain about S pole and N pole of magnetic field generated by electric current.



#### Note

Through the experiment above, we could confirm magnetic fields occur around the wire carrying electric current. Also, we could confirm the magnetic fields change if the direction of current flow changes. By using magnetic compasses, we could confirm Ampere's Right-hand grip rule.