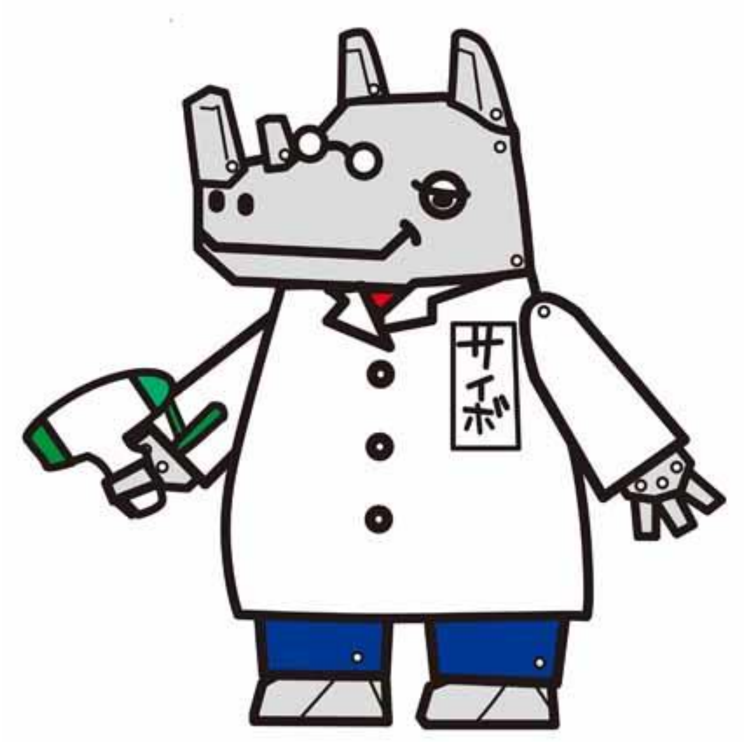
Selection
of
Dynamic Electricity
Experiments



NaRiKa Corporation

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Generating Magnetic Field by Electric Current 1

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.

Learning outcome of this Unit is for students to better understand the phenomena of experiment of H. C. Oersted through their hands-on experience.

2. Historical Background

Unlike dynamics, study on Electromagnetism is believed to have remained less-advanced due to its nature of handling with invisible events. Up until W. Gilbert (1544 - 1603, 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 (1745 - 1827, 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.

W. Gilbert

http://es.wikipedia.org/wiki/William Gilbert

A. Volta

http://en.wikipedia.org/wiki/Alessandro_Volta

Voltaic Cell was used by many researchers for its capability of generating large amount of electric current at low voltage. Notable study was made by H. C. Oersted (1777 - 1851, Denmark) when he discovered that compass needle should deflect near a lead carrying current, which was made public as article named "Interaction of Current and Magnetism" in 1820.

It is commonly believed that A. M. Ampere made public his theory of Electricity and Magnetism in the same year, because he was deeply impressed with Oersted's report then, established basis of Electrodynamics. Hence, in this Unit, we will focus on replicating the experiment of H. C. Oersted, who is assumed to be the father of Electrodynamics and Electromagnetism, which is meaningful nowadays even for us.

3. Introduction of Equipment for Experiments

Genecon V3 is a product name of 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

Genecon V3 (Narika B10-2634)

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.

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 transplant body. For teachers, Genecon V3 significantly helps their explanation to students regarding the fact that motor and generator are identical.

4. Inspection of Equipment and Preliminary Experiment

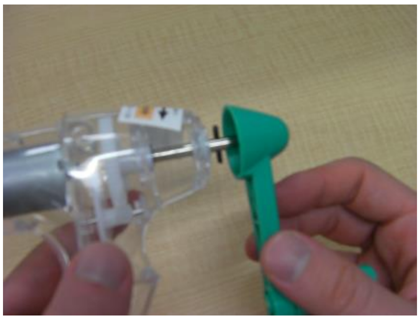
Preliminary experiment is mandatory step by teachers to check the procedure of experiment and detect any defect/failure of the instrument to be used, prior to the experiment by students. In this unit, check Genecon V3 with the procedure mentioned below.

1) Procedure for Genecon V3 operation check

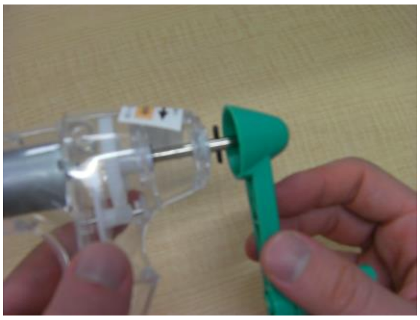
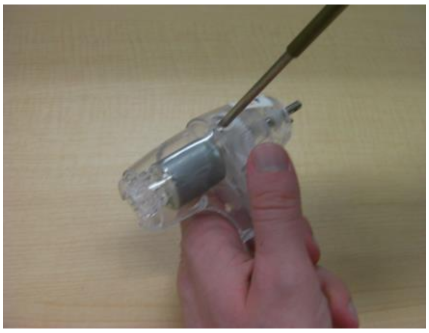
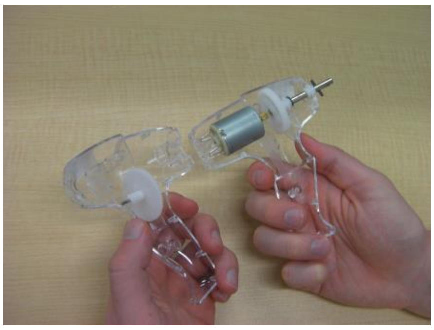
Steps	What to do	Actions
1	Connect miniature-bulb-adapter with Genecon V3. Or, connect Genecon V3 with the "Miniature Bulb Holder with Leads" through the "Lead for Genecon V3 with Alligator-clips". (Note: The photo shown on the right is using miniature-bulb-adapter.)	
2	Turn the handle of a Genecon V3 gently both clockwise and anti-clockwise.	
3	Check if the handle is rotating smoothly.	In case you find the handle is loosely rotating, fix it following the below procedure 2) a). In case you find breakage with gear(s), change the gears following the below procedure 2) b).
4	Check if the bulb of the miniature-bulb-adapter (or of the holder) is lit.	In case it is not, change the bulb to a new bulb.

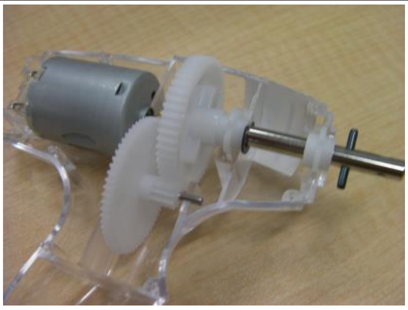
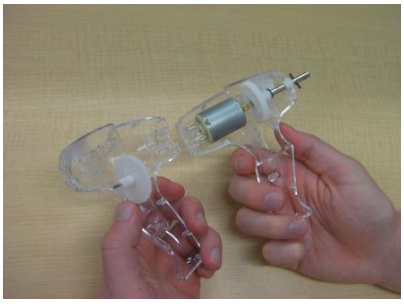
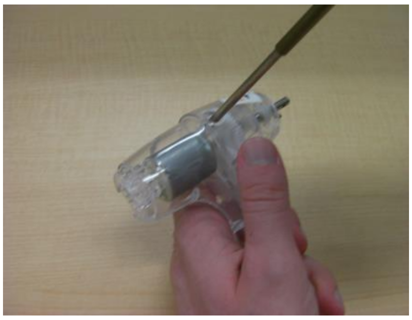
2) Maintenance of Genecon V3

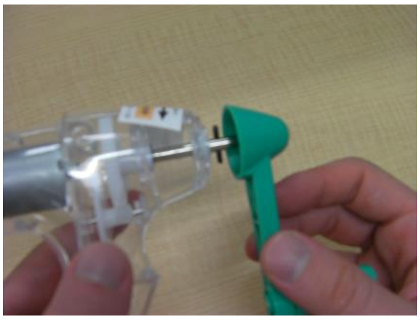
a) How to fix the handle

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	
2	Engage the handle firmly with the shaft.	
3	Return the set screw again to the handle.	
4	Firmly fix the set screw using a hexagon wrench.	

b) How to replace the gear(s)

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	
2	Take out the handle out of the shaft.	
3	Detach the head capsule with fingers. If needed, use a flat-blade screwdriver.	
4	Take out the two screws used for the body using a phillips-head screwdriver.	
5	Dismantle (split up) the body into two parts.	

<table>
<tr><th>Steps</th><th>What to do</th><th>Actions</th></tr>
<tr><td>6</td><td>Take out the installed gears.</td><td></td></tr>
<tr><td>7</td><td>Replace the damaged gear(s).</td><td rowspan="3"></td></tr>
<tr><td>8</td><td>Set all the gears again in the body.</td></tr>
<tr><td>9</td><td>Set the two “guiding spacers” of the shaft-with-gear at the predetermined location.</td></tr>
<tr><td>10</td><td>Assemble the body.</td><td></td></tr>
<tr><td>11</td><td>Fix the assembled body with the two screws using a phillips-head screwdriver.</td><td></td></tr>
<tr><td>12</td><td>Attach the head capsule.</td><td></td></tr>
</table>

<table>
<tr><th>Steps</th><th>What to do</th><th>Actions</th></tr>
<tr><td>13</td><td>Engage the handle with the shaft.</td><td></td></tr>
<tr><td>14</td><td>Fix the handle with set screw using a hexagon wrench.</td><td></td></tr>
<tr><td>15</td><td>Operation check by rotating the handle.</td><td></td></tr>
<tr><td colspan="3">
Replacement Gear Set for Genecon (Narika B10-2632-V9)</td></tr>
</table>

5. Teaching Scheme

Choose either Experiment 1 or 2 below, followed by Experiment 3.

	Teaching Schemes	What to teach?	What to emphasize? (Precautions)	Class-time-duration
1	Introduction	● Explain the historical background. ● Electrical current generates magnetic field.	● Introduction to Electrodynamics and Electromagnetism	5 min
2	Experiment 1	● Perform experiment using a circuit with dry cell batteries. ● During the experiment, always be aware of the polarity. ● Also, designate the North/South poles of the oil-filled magnetic compass.	● Use a switching device in the circuit. ● Place the oil-filled magnetic compass near the conducting wire. ● Change the polarity of the dry cell batteries. ● Designate the North/South poles of the oil-filled magnetic compass.	10 min
3	Experiment 2	● Connect a Genecon V3 to the circuit. ● Designate the North/South poles of the oil-filled magnetic compass. ● Occasionally reverse the direction of turning Genecon V3's handle in order to change the polarity. ● Realize the current and voltage change depending on the intensity of turning Genecon V3's handle.	● All the time, pay attention to the polarity of the electricity being generated by Genecon V3. ● Place the oil-filled magnetic near the cable. ● Designate the North/South poles of the oil-filled magnetic compass. ● Realize the current and voltage change depending on the direction and intensity of turning Genecon V3's handle.	10 min
4	Summary	● How to report the result designating the North/South poles of the oil-filled magnetic compass. ● Realize the direction of the current flow in the circuit. (Polarity of dry cell battery).	● Repeat the experiment in case needle deflection is too imperceptible to detect the current flow. ● In such a case, change the dry cell battery to a new one.	5 min
5	Experiment 3	● Choose either of Genecon V3 or dry cell battery for the power unit. ● Change the positional relation of the lead and oil-filled magnetic compass. ● Fix the positional relation of the lead and oil-filled magnetic compass as the students decide.	● Pay attention to the direction of current flow. ● Pay attention to the position of each of the North/South poles of the oil-filled magnetic compass.	10 min
6	Wrap-up and Presentation by Students	● Phenomenon of needle deflection of an oil-filled magnetic compass influenced by current flow. ● Direction of the needle deflection of an oil-filled magnetic compass changes depending on the direction of current flow. ● Amplitude of the needle deflection of an oil-filled magnetic compass changes depending on amount of current. ● Assign student(s) who makes presentation.	● Intentionally do not introduce the magnetic field that appears around the lead when it carries current. ● Answer the students' question regarding the magnetic field that appears around the cable, if any.	30 min

6. Experiment for Students – Excerpted from Students' Worksheet

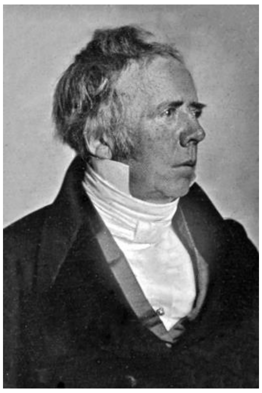
Generating Magnetic Field by Electric Current 1

1. Formation of Magnetic Field by Electric Current ~H. C. Oersted~

Only after the discoveries of static electricity related research by W. Gilbert made in 1600, L. Galvani discovery of bioelectric in 1791, and A. Volta's discovery of battery in 1800, further research activities on low voltage and high current electricity took place one after another.

Danish H. C. Oersted (Ørsted) discovered in 1820 that electric current generates magnetic field (interaction of current and magnetism). It is said that, by this discovery, A. M. Ampere was able to reach a stage where he could publish his theory of electricity and magnetism, establishing the modern days theory of electrodynamics.

In this Unit, we will perform the experiment of generation of magnetic field by current experiment done by H. C. Oersted, who contributed greatly to the development of electricity, to understand basic behavior of electric current.



http://en.wikipedia.org/wiki/Hans_Christian_ Ørsted

2. Oersted's Experiment

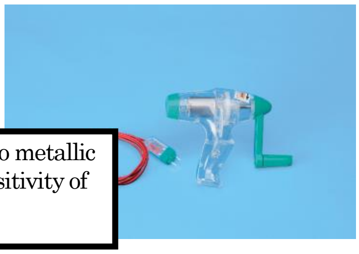
1. Purpose of the experiment:

Purpose of this experiment is, by using dry cell battery, Genecon V3 and magnetic compass, to confirm that generation of magnetic field depends on electric current flowing through cable.

2. What to Prepare:

*Genecon V3: 1 pc (Narika B10-2634)
*Oil-filled Magnetic Compass: 1 pc (Narika B10-3570)
*Miniature Bulb Holder with Leads: 1 pc (Narika P70-0395-01)
*Dry cell battery (AA type): 1 pc (Narika P70-0719-03, 20pcs)
*Battery box with switch: 1 pc
*Cable with clips (red and black): 1 pair (Narika B10-6503)
* Wooden plate: 1 pc (10 x 200 x 300 mm): 1 pc

Pay special attention to metallic table as it reduces sensitivity of the compass.

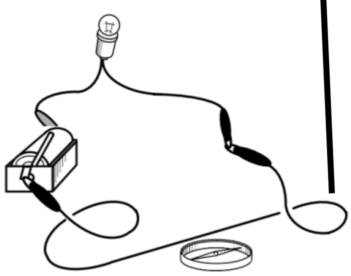


Genecon V3

3. Experiment 1: Experiment using Dry cell batteries

1) Place wooden plate on the table.
2) On the wooden plate, set a battery box with switch and put inside prepared dry cell battery.
3) Create electric circuit by connecting: a miniature bulb holder with cable, a cable with clips and terminals of battery box together like in the drawing on the right. Keep the battery box switched off.
4) Place an oil-filled magnetic compass about 1 cm away from the cable.
Tips: Make sure to set the compass needle and cable in parallel.
5) Switch on the battery box. Check the deflection of the compass needle caused by the electric current, and write it down.

Experiment may fail if the compass is placed too close to the cable.



6) Change polarity of the battery in step 2, repeat steps 3-5, and check the change in the deflection of the compass needle caused by electric current and write it down too.

7) Switch off the battery box.

4. Experiment 2: Experiment using Genecon V3

Pay special attention to metallic table as it reduces sensitivity of the compass.

1) Place wooden plate on the table.

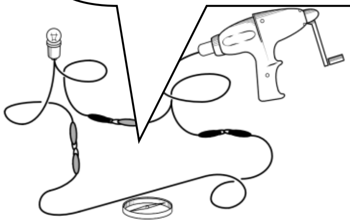
2) On the wooden plate, connect a "miniature bulb holder with cable" and "cable with clips" with a Genecon V3.

3) Place an oil-filled magnetic compass about 1 cm away from the cable. Tips: Make sure to set the compass needle and cable in parallel.

4) Turn the handle of Genecon V3. Check the deflection of the compass needle caused by the electric current, and write it down.

5) Change the direction of turning the handle. Check the change in the deflection of the compass needle caused by electric current and write it down too.

Pay special attention to the polarity caused by the way of connecting Genecon V3.



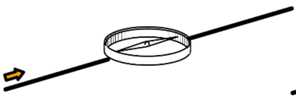
5. Experiment 3: Experiment with different place setting of magnetic compass

1) During experiments 1 and 2, we placed compass about 1 cm away from cable, but now let's change the place where we put compass and conduct experiments.

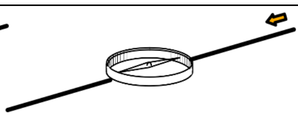
2) Perform experiments 1 or 2 with compass placed in positions as shown on drawings below (a) to (f). For drawings (g) and (h), think about suitable position by yourself and do the experiment.

3) Verify every pattern of deflection of compass needle caused by electric current per experiment condition, and write it down.

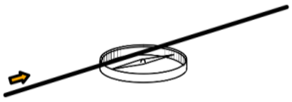
Pay attention to the direction of the current flow.



(a)



(b)



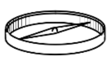
(c)

(d)

(e)

(f)

Freely change the position of the cable and compass.



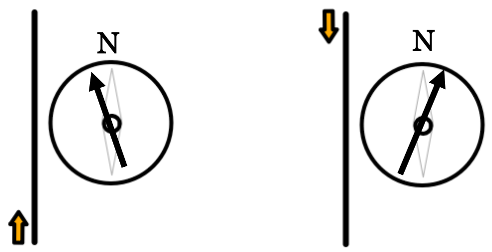
(g)

(h)

3. Summary of Oersted Experiment

1. Results of Experiment 1 and Experiment 2

Please draw down direction (deflection state) of movement of compass needle.

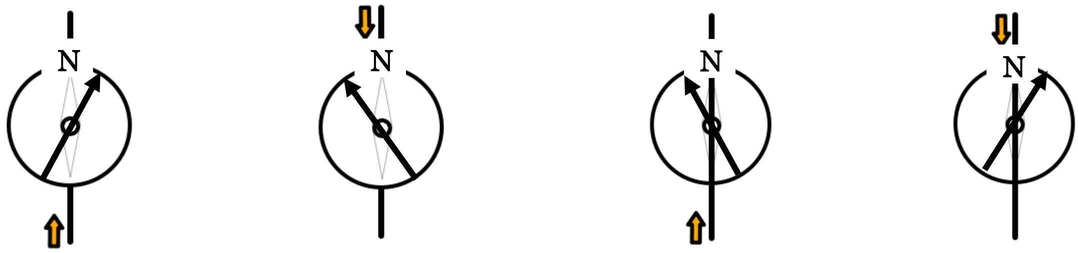


(1) (2)

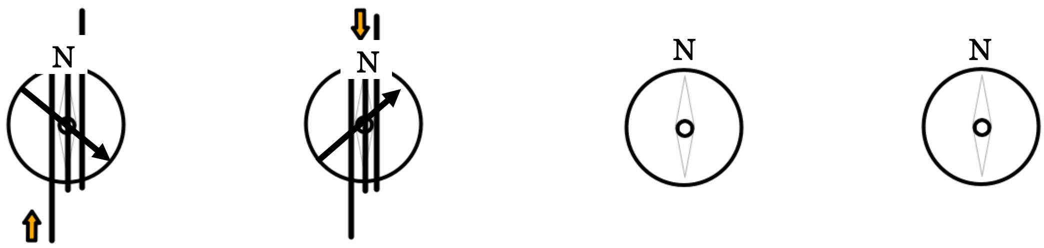
[What you should find out:]
In case the North pole is placed "Up" (further from where the experimenter stands), the direction of the needle deflection differs depending on the direction current flows.
In case of (1), North pole is attracted toward the cable, which means the cable assumed the properties of the South pole affected by the influence of current flow.
On the other hand, in case of (2), North pole repulses the cable, which means the cable assumed the properties of the North pole affected by the influence of current flow. .

2. Result of Experiment 3

Please draw down direction (deflection state) of movement of compass needle.



(a) (b) (c) (d)



(e) (f) (g) (h)

[What you should find out:]
By comparing the result of "Experiment 1 or 2" and "Experiment 3", you will realize that three of the patterns (1), (a) and (c) have the same condition in terms of the direction of current flow, while they have different condition in terms of the position of compass. In case of the pattern (a), setting the compass on the cable, the needle of the compass will be deflected to the left. In case of the pattern (c), setting the compass beneath the cable, the needle will be deflected to the right. In case of the pattern (1), setting the compass on the right side of the cable, the needle will be deflected to the left. From these results, magnetic field that affects the compass seems to be generated around the cable when current is carried.

Likewise, you will realize that three of the patterns (2), (b) and (d) have the same condition in terms of the direction of current flow (opposite to above), while they have different condition in terms of the position of compass. If comparing with above, you will know the direction of magnetic field changes depending on the direction of current carried in the cable.

In case of pattern (e) and (f), the cable is coiled around the compass in solenoidal manner. According to the results, you will know the left side of the solenoid turned South pole in case of (e), while the right side of the solenoid turned South pole in case of (f), which means the direction of current flow determines North/South pole beside solenoid coil.

Note

Advanced interpretation based on “Ampere's law” (Right-hand grip rule) might be effective for students’ better understanding, while it is true that figuring out the whole magnetic field generated around the cable is tough for many of the students in the above experiments. It is recommended that you should introduce the “Ampere's law” only when some students have already learned it.

Hence, the learning outcome should be:

1. Magnetic field sufficient to affect compass is generated around the cable by the current flow carried in the cable.
2. If the direction of current flow is switched to the opposite, magnetic field, which is opposite to above, is generated around the cable by the current flow carried in the cable.
3. Degree of needle deflection differs depending on the amount of current carried in the cable.

Generating Magnetic Field by Electric Current 2

1. Learning Outcome

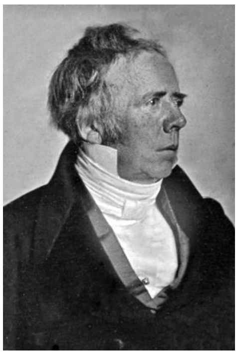
While experiments on Electric Current and Magnetic Field are normally done by using dry cell batteries or electric power-supply units, we are going to use the hand-held generator "(Narika) Genecon V3" in this Unit. In case of using dry cell batteries or electric power-supply units, students can merely 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 1st, 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.



Hans Christian Ørsted
http://en.wikipedia.org/wiki/Hans_Christian_ Ørsted

A. M. Ampere
http://en.wikipedia.org/wiki/File:Ampere_Andre_1825.jpg

[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 9th 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 2×10^{-7} newtons per meter of length". The 10th 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)

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

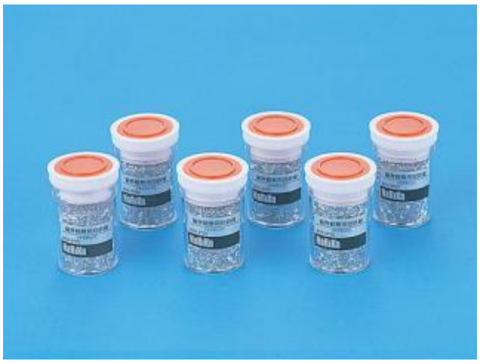
Experimental apparatus used for confirming Ampere's Right-handed Grip Rule normally requires large current of 30A, however power supply unit for such large current is generally not available in most of schools. Furthermore, due to its high risk, usage of such apparatus is limited to the demonstration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

Ampere Apparatus
(Narika B10-4753)

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 Geencon V3 as the power source.

[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. Inspection of Equipment and Preliminary Experiment

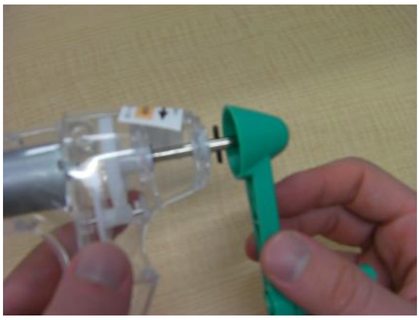
Preliminary experiment is mandatory step by teachers to check the procedure of experiment and detect any defect/failure of the instrument to be used, prior the experiment by students. In this Unit, check the Genecon V3 and Ampere Apparatus with the procedure mentioned below.

1) Procedure for Genecon V3 operation check

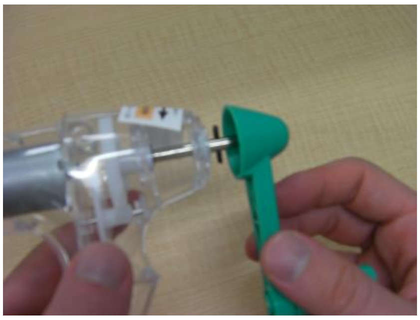
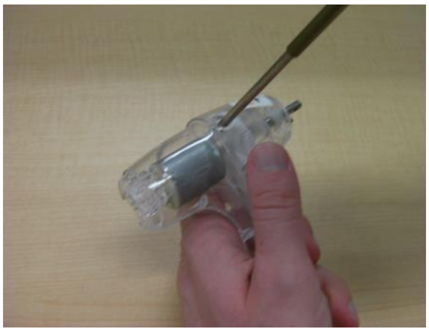
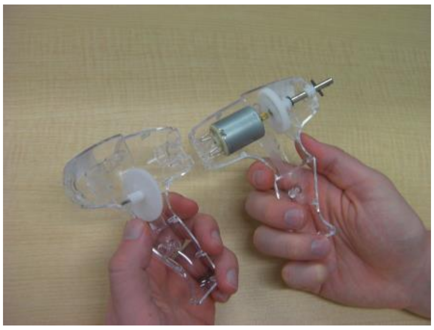
Steps	What to do	Actions
1	Connect the miniature-bulb-adapter with Genecon V3. Or connect Genecon V3 with the "Miniature Bulb Holder with Leads" through the "Lead for Genecon V3 with Alligator-clips". (Note: The photo shown on the right is using miniature-bulb-adapter.)	
2	Turn the handle of a Genecon V3 gently both clockwise and anti-clockwise.	
3	Check if the handle is rotating smoothly.	In case you find the handle is loosely rotating, fix it following the below procedure 2) a). In case you find breakage with gear(s), change the gears following the below procedure 2) b).
4	Check if the bulb of the miniature-bulb-adapter (or, of the holder) is lit.	In case it is not, change the bulb to a new bulb.

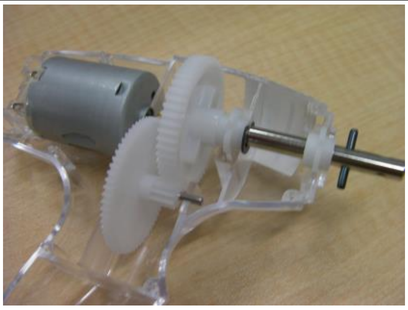
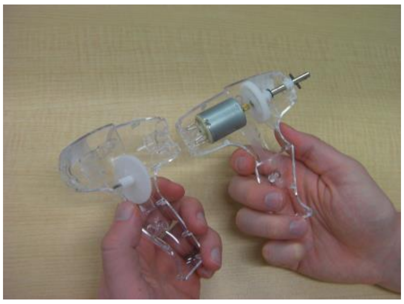
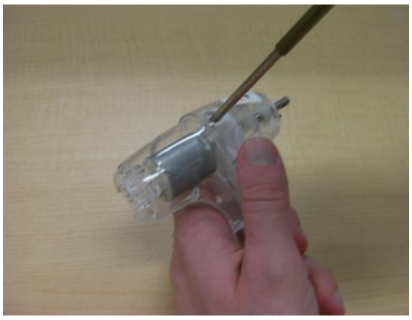
2) Maintenance of Genecon V3

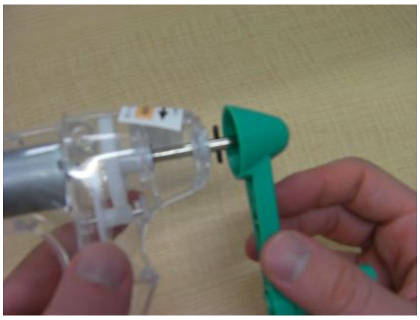
a) How to fix the handle

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	
2	Engage the handle firmly with the shaft.	
3	Return the set screw again to the handle.	
4	Firmly fix the set screw using a hexagon wrench.	

b) How to replace the gear(s)

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	
2	Take out the handle out of the shaft.	
3	Detach the head capsule with fingers. If needed, use a flat-blade screwdriver.	
4	Take out the two screws used for the body using a phillips-head screwdriver.	
5	Dismantle (split up) the body into two parts.	

Steps	What to do	Actions
6	Take out the installed gears.	
7	Replace the damaged gear(s).	
8	Set all the gears again in the body.	
9	Set the two "guiding spacers" of the shaft-with-gear at the predetermined location.	
10	Assemble the body.	
11	Fix the assembled body with the two screws using a phillips-head screw driver.	
12	Attach the head capsule.	

Steps	What to do	Actions
13	Engage the handle with the shaft.	
14	Fix the handle with set screw using a hexagon wrench.	
15	Operation check by rotating the handle.	

Replacement Gear Set for Genecon (Narika B10-2632-V9)

3) **Procedure for Ampere Apparatus operation check**

Steps	What to do/Action
1	Connect Ampere Apparatus to DC Power Supply Unit.
2	Switch on the DC Power Supply Unit and increase the current until the ammeter needle indicates around 2A.
3	If the needle of ammeter changed and stays changed, the operation of Ampere Apparatus has no problem. (Note: Disregard deflection of voltmeter) Otherwise, go to step 4.
4	Fuse inside the Ampere Apparatus has blown out. Replace it with a new 3A straight pipe type fuse.
5	Repeat steps 2 and 3 to check the apparatus operation.

5. Teaching Scheme

Choose either of Experiment 1 or 2 below, followed by Experiment 3.

	Teaching Schemes	What to teach?	What to emphasize? (Precautions)	Class-time-duration
1	Introduction	●Historical background ●The Ampere's Rule	●Introduction to Electrodynamics and Electromagnetism. ●"Ampere's law" (Right-hand grip rule).	10 min
2	Experiment 1 Experiment using Genecon V3 as the power source	●Make pairs of two students. ●Experiment using both of "Single Wire (U-shaped Type)" and "Solenoid Wire". ●How to make a sketch of the pattern of "Mag Chip" around the wire. ●Continue the experiment by changing the direction of turning Genecon's handle.	●One student turns the handle of Genecon V3 and the other student makes a sketch of the patterns of "Mag Chip". ●During each round for observation, turn the handle of Genecon V3 only in one direction. ●Tap the side of the Ampere Apparatus so as to help it better/clearer form the pattern of "Mag Chip". ●Each student make his/her experiment in alternate shifts.	10 min
3	Experiment 2 Experiment using Power Supply Unit as the power source	●Connect the Ampere Apparatus to the power supply unit. ●Turn up the volume of power supply unit until it indicates the current value of 3A. ●Experiment using both of "Single Wire (U-shaped Type)" and "Solenoid Wire". ●How to make a sketch of the pattern of "Mag Chip" around the wire. ●Continue the experiment by changing the polarity of the power supply.	●Be careful not to increase electrical current over 3A. Fuse inside the Ampere Apparatus may blow out due to the heat. ●Complete the experiment within a time limit of 1 minute to avoid excessive heating. ●Set a time interval between experiment rounds that is long enough to cool down the wire.	10 min
4	Experiment 3 Experiment using magnetic compass	●Place four of small size magnetic compasses at equally-spaced intervals around the wire. ●Observe the small magnetic compass focusing on how it will be affected by the magnetic field generated by DC power supply unit (Experiment 1) and/or Genecon V3 (Experiment 2).	●The wire of the apparatus has to be directed parallel to the North pole of magnetic compass. ●Tap the compass when the needle is stuck.	10 min
5	Summary and Presentation by Students	●Check the pattern of "Mag Chip" generated around the wire carrying electric current. ●Check how either end of compass needle (North pole side or South pole side) moves. ●Based on above results, figure out the flow direction (from North pole to South) of the magnetic field around the wire. ●Collate the result with the Ampere's law.	●The spiral pattern formed by "Mag Chip" shows the magnetic field. ●Flow direction of magnetic field can be identified by the indicated direction of magnetic compass.	20 min

6. Experiment for Students – Excerpted from Students' Worksheet

Generating Magnetic Field by Electric Current 2

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 generate 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.

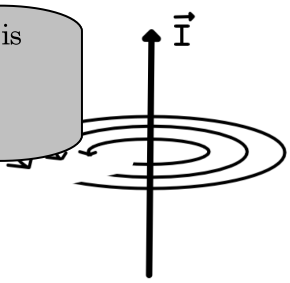
[1.] Ampere discovered that magnetic field is spirally generated around the electric current flowing in the direction toward which "Right Screw" is tightened. In other words, magnetic field is generated around current flow. This is called Right-hand rule (or Right-hand grip rule) (see the figures below).

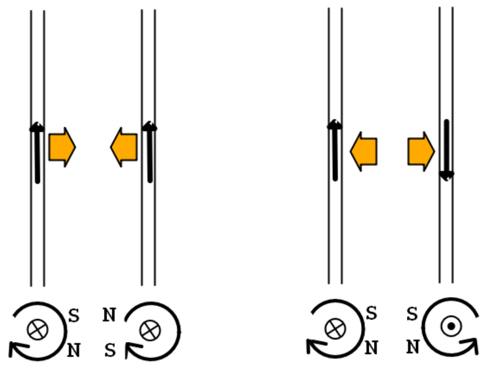
[2.] By using two conductive wires carrying electric current to observe magnetic action between them, he examined repulsive magnetic action occurs when the wires carry the current toward opposite direction, while attractive magnetic action occurs when the wires carry the current toward same direction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

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

http://en.wikipedia.org/wiki/File:
Ampere_Andre_1825.jpg

Experiments shown hereunder is to be made to understand the Right-hand rule.





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

$$2\pi r H = I \qquad H = \frac{I}{2\pi r}$$

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)
*Oil filled compass:	10 pcs (Narika B10-3589-02)

Genecon V3
(Narika B10-2634)

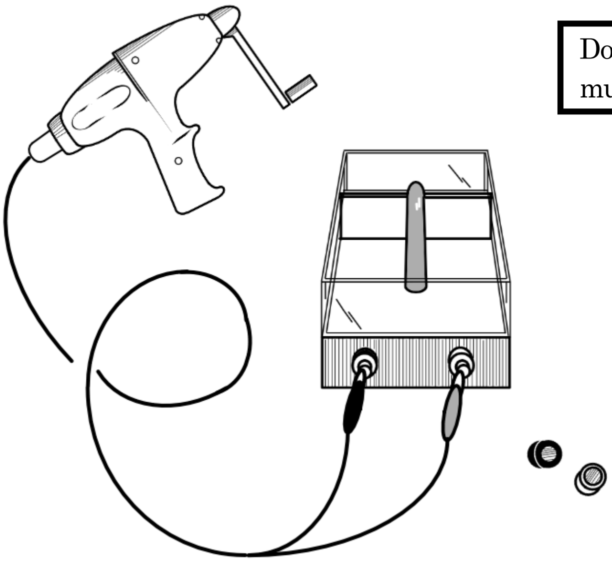
Mag Chips
(Narika B10-3720)

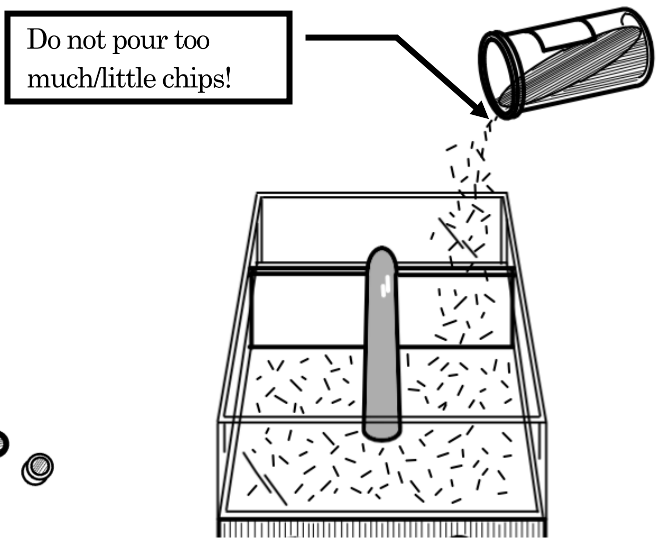
Ampere Apparatus
(Narika B10-4753)

3. Experiment 1: Experiment using GeneconV3

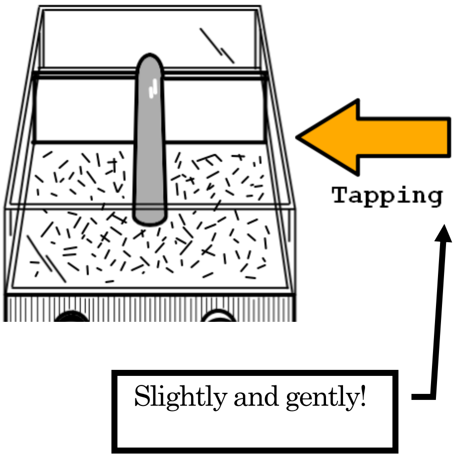
Make experiment by taking turns.

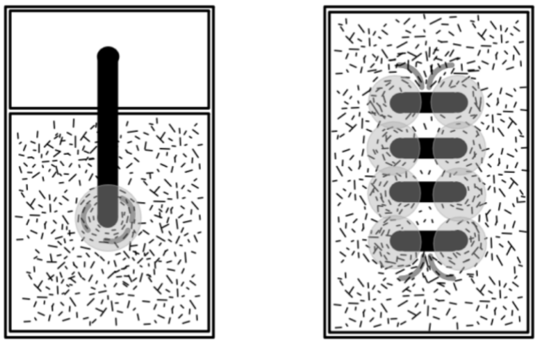
1) Make pairs.
2) Remove the plastic covers from terminals (red and black) on observation unit with single wire.
3) Connect the cable with clips (red and black) of Genecon V3 to the metal part of the terminals (red and black).
4) Pour Mag Chips to the observation unit (front part) and spread them evenly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





5) One person will start turning the handle of Genecon V3 as fast as possible.
6) The other person will start taping the side of the Apparatus (single wire) by his/her finger.
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 Ampere Apparatus (Solenoid).
10) Draw the shape (pattern) of the electric fields in the figures below.

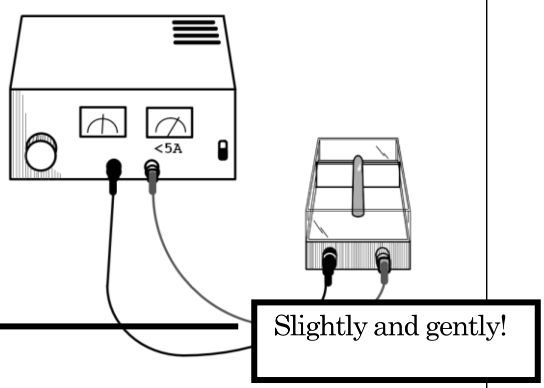




4. Experiment 2: Experiment using Power Supply Unit

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.
3) Switch on the Power supply unit and set current value to 3 A.

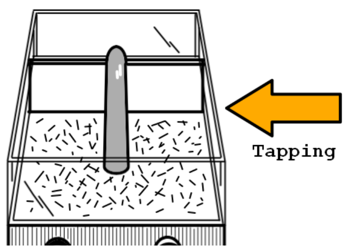
<u>Attention: If Power supply unit is on for more than 1 minute, connecting cables will became hot. Therefore be careful not to melt down the cable jacket.</u>

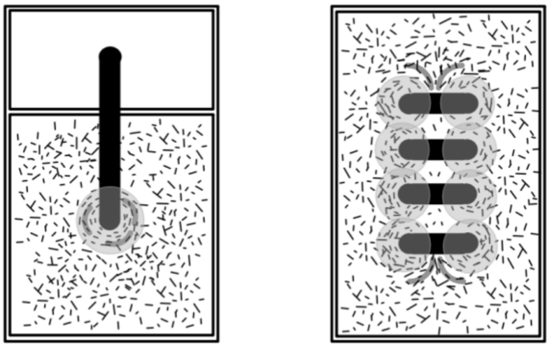


4) One person will start taping the side of the Apparatus (single wire) by his/her finger.
5) Make sure whether you can see in the observation unit of Ampere Apparatus (single wire) electric field.
6) After you could see the magnetic field, switch off the Power supply unit.

<u>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.</u>

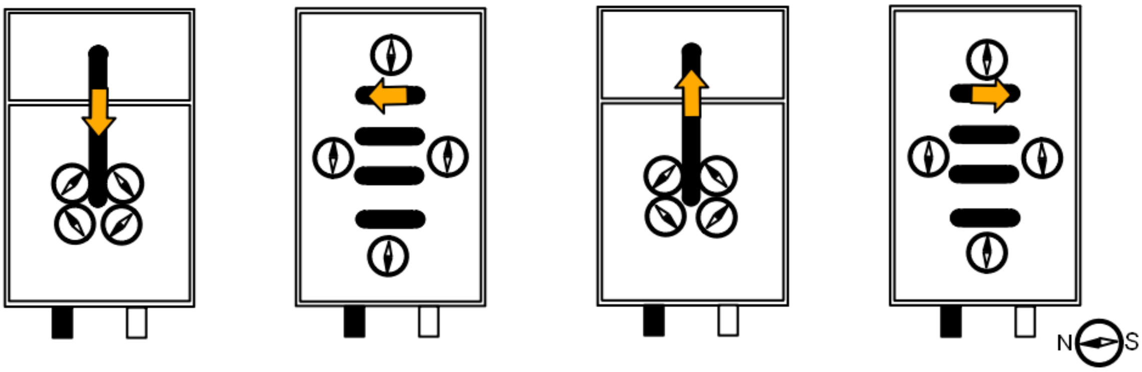
7) Do in the same way steps 1-6, this time with Ampere Apparatus (Solenoid).





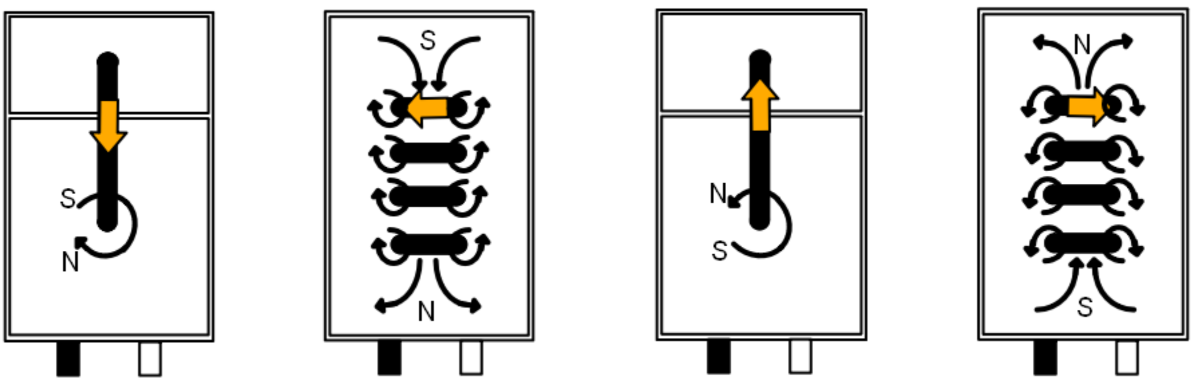
5. Experiment 3: Experiment using Magnetic Compass

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.

Generating Magnetic Field by Electric Current 3

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.

Students should have better understanding of the nature of and interaction between "Magnetic and Electric Current" through the experiment of Oersted and Ampere's law introduced in the previous two Units, "Generating Magnetic Field by Electric Current 1 & 2". In this Unit, we are going to learn through experiments about electromagnet.

2. Historical Background

Up until W. Gilbert (1544 - 1603, 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 (1745 - 1827, 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.

A. M. Ampere
http://en.wikipedia.org/wiki/File:Ampere_Andre_1825.jpg

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 1st, 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, which is called the dawn of Electromagnetics.

Joseph Henry
http://www.photolib.noaa.gov/bigs/pers0124.jpg

In 1826, Ohm made his research publication of "Ohm's law", followed by the discovery of electromagnet by William Sturgeon (1783 - 1850, UK) in 1828. Conceived from the Solenoid Wire experiment done by Ampere, Sturgeon found that iron block with coiled wire became magnetized when electric current is carried through the wire. In 1829, Joseph Henry (1797 - 1878, USA) succeeded in creating high-powered magnet, as well as, in discovering self-induction and electromagnetic induction during his research on electromagnetism, whose achievement on electromagnetic induction was conceded to Michael Faraday (UK) merely because Faraday's presentation preceded before Henry's.

In this Unit, we will learn about the basic properties of electromagnet by using Genecon V3. We learned about Ampere's Right-handed Screw Rule showing that magnetic field is generated around the coiled wire(s) when electric current is carried though. Hereinafter, we will learn through experiments that: 1) the coiled wire becomes magnetized when metallic bar (core) is inserted, and 2) the power of the electromagnet changes depending on the coil turns.

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 transplant body. For teachers, Genecon V3 significantly helps their explanation to students regarding the fact that motor and generator are identical.

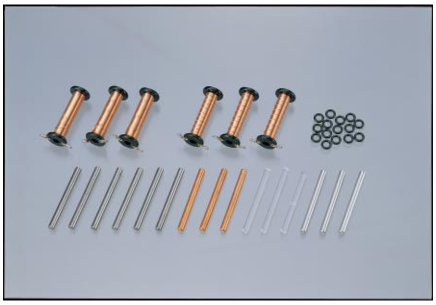
[2] Replacement Gear Set for Genecon V3:

Genecon V3 consists of plastic gears, motors and others. In particular, the gears are subject to wear, and eventually break causing strange noise and free-spin. Thai is why Narika provides "Replacement Gear Set for Genecons". Also, Genecon V3 was designed taking into account user-friendliness for teachers who would like to change the gears by themselves.

[3] Coil Set for Electromagnet:

Sold in three (x3) sets with (2 types of) solenoidal coils and (4 types of) bar-cores. This set is suitable for confirming how electromagnet changes depending on the coil turns and/or the type of bar-core material by using in combination with Genecon V3, dry cell batteries or power supply unit.

Solenoid coil 100 turns: 3 pcs
Solenoid coil 200 turns: 3 pcs
Core metal (Copper, Aluminum, Glass): x 3 each
Core metal (Iron): x 6 each
O-ring (rubber): 15 pcs



Coil Set for Electromagnet (3 sets)
(Narika S75-5606)

4. Inspection of Equipment and Preliminary Experiment

Preliminary experiment is mandatory step by teachers to check the procedure of experiment and detect any defect/failure of the instrument to be used, prior the experiment by students. In this Unit, check the Genecon V3 and Ampere Apparatus with the procedure mentioned below.

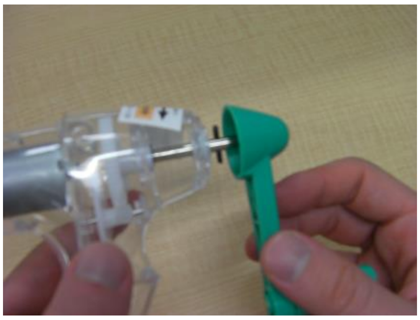
1) Procedure for Genecon V3 operation check

Steps	What to do	Actions
1	Connect the miniature-bulb-adapter with Genecon V3. Or connect Genecon V3 with the "Miniature Bulb Holder with Leads" through the "Lead for Genecon V3 with Alligator-clips". (Note: The photo shown on the right is using miniature-bulb-adapter.)	
2	Turn the handle of a Genecon V3 gently both clockwise and anti-clockwise.	
3	Check if the handle is rotating smoothly.	In case you find the handle is loosely rotating, fix it following the below procedure 2) a). In case you find breakage with gear(s), change the gears following the below procedure 2) b).
4	Check if the bulb of the miniature-bulb-adapter (or, of the holder) is lit.	In case it is not, change the bulb to a new bulb.

2) Maintenance of Genecon V3

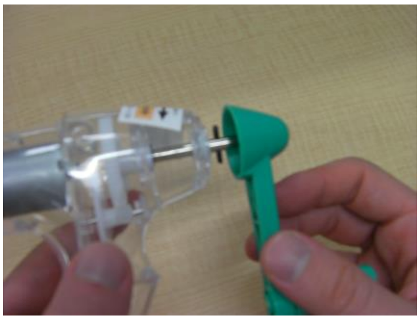
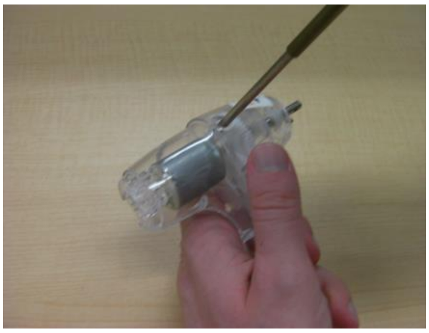
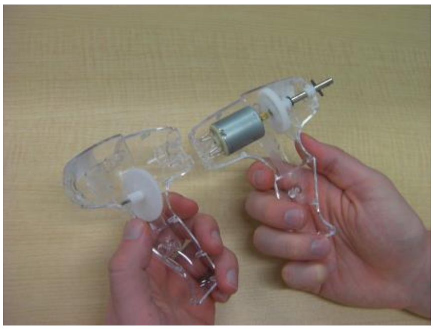
a) How to fix the handle

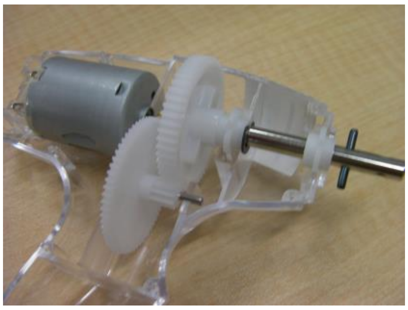
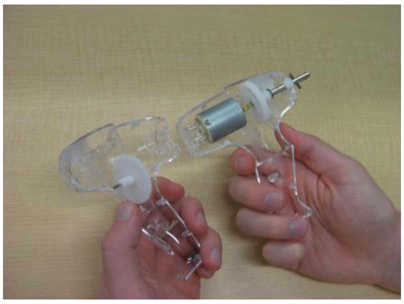
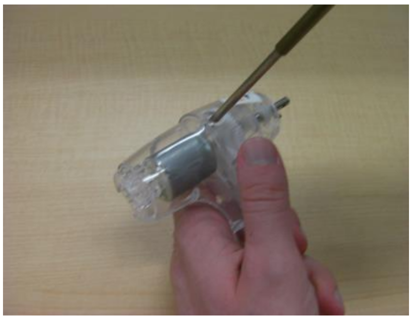
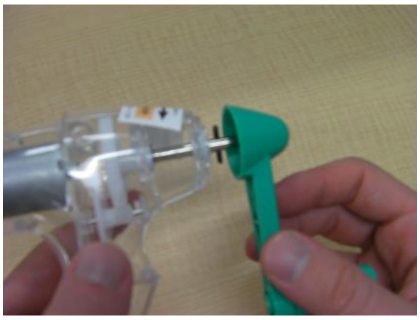
Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	

Steps	What to do	Actions
2	Engage the handle firmly with the shaft.	
3	Return the set screw again to the handle.	
4	Firmly fix the set screw using a hexagon wrench.	

b) How to replace the gear(s)

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	

Steps	What to do	Actions
2	Take out the handle out of the shaft.	
3	Detach the head capsule with fingers. If needed, use a flat-blade screwdriver.	
4	Take out the two screws used for the body using a phillips-head screw driver.	
5	Dismantle (split up) the body into two parts.	
6	Take out the installed gears.	

Steps	What to do	Actions
7	Replace the damaged gear(s).	
8	Set all the gears again in the body.	
9	Set the two “guideing spacers” of the shaft-with-gear at the predetermined location.	
10	Assemble the body.	
11	Fix the assembled body with the two screws using a phillips-head screw driver.	
12	Attach the head capsule.	
13	Engage the handle with the shaft.	

Steps	What to do	Actions
14	Fix the handle with set screw using a hexagon wrench.	
15	Operation check by rotating the handle.	

5. Teaching Scheme

<table>
<tr><th></th><th>Teaching Schemes</th><th>What to teach?</th><th>What to emphasize?
(Precautions)</th><th>Class-time-duration</th></tr>
<tr><td>1</td><td>Introduction</td><td>● Historical background
● The Ampere's Rule</td><td>● Introduction to Electrodynamics and Electromagnetism.
● "Ampere's law" (Right-hand grip rule).</td><td>10 min</td></tr>
<tr><td>2</td><td>Experiment 1
Solenoid coil 100 turns only</td><td>● Make pairs of two students.
● Check with the students if they are aware of the magnetic field generated around the coil in accordance with Ampere's Right-hand grip rule.</td><td rowspan="3">● One of the paired students turns the handle of Genecon V3.
● The other student bring the coil near metal paper clips.
● Each student continue his/her experiment by taking turns.</td><td rowspan="3">30 min</td></tr>
<tr><td>3</td><td>Experiment 2
Check the difference in the number of solenoid coil turns</td><td>● Make pairs of two students.
● Insert an iron bar in the coil used for Experiment 1.
● Change from the coil of 100 turns to 200 turns.
● Confirm that the magnetic force is strengthened if an iron bar is inserted.
● Confirm that the magnetic force is strengthened if coil with more turns is used.</td></tr>
<tr><td>4</td><td>Experiment 3
Check the difference in the types of core bar inserted in solenoid coil</td><td>● Compare each type of the bar material with reference to the iron bar used in Experiment 2.
● Continue the experiment changing the bar material from iron to copper, aluminum and glass.
● Continue the experiment using both coils of 100 turns and 200 turns.
● Check how the magnetism changes depending on the intensity of turning the handle of Genecon.</td></tr>
<tr><td>5</td><td>Summary</td><td>● Urge the students to record the result on worksheet.
● Urge each student to make his/her presentation on the summary section in student's worksheet.</td><td>● Try to cascade what the students learned in this Unit to the next.</td><td>20 min</td></tr>
</table>

6. Experiment for students – Excerpted from Students' Worksheet

Generating Magnetic Field by Electric Current 3

1. Formation of Magnetic Field by Electric Current ~William Sturgeon & Joseph Henry~

The year 1820 is called the dawn of Electromagnetics, when H. C. Oersted (Denmark) discovered electric current form magnetic field, followed by A. M. Ampere (France) who made public on his theory of Electricity and Magnetism.

In 1826, Ohm (1789 - 1854, Germany) made his research publication of "Ohm's law", followed by the discovery of electromagnet by William Sturgeon (UK) in 1828. From the idea of Solenoid Wire experiment by Ampere, Sturgeon found that iron block with coiled wire became magnetized only when electric current is carried through the wire.

In 1829, by improving William Sturgeon's electromagnet, Joseph Henry (USA) succeeded in creating high-powered magnet strong enough to lift up a mass of 1 ton. He discovered self-induction and electromagnetic induction during his research on electromagnetism. His achievement on electromagnetic induction was conceded to Michael Faraday (UK) merely because Faraday's presentation preceded before Henry's.

Joseph Henry

http://www.photolib.noaa.gov/bigs/pers0124.jpg

In this Unit, we are going to learn about the basic properties of electromagnet through the experiments discovered by the pioneer researchers.

2. Experiment with Electromagnet

1. Purpose of this experiment:

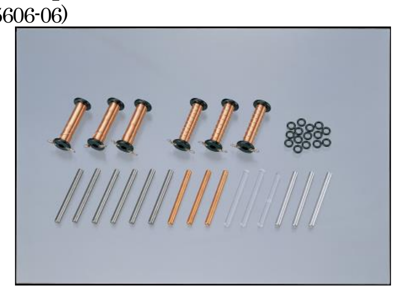
Under what conditions is electromagnet made, and what are the factors that determine strength of electromagnet.

2. What to prepare:

*Genecon V3: 1 pc
(Narika B10-2634)
*Solenoid coil (100 windings): 1 pc
(Narika S75-5606-01)
*Solenoid coil (200 windings): 1 pc
(Narika S75-5606-02)
*Paper clips (steel): around 20 pcs

*Core (copper): 1 pc
(Narika S75-5606-03)
*Core (aluminum): 1 pc
(Narika S75-5606-04)
*Core (glass): 1 pc
(Narika S75-5606-05)
*Core (iron): 1 pc
(Narika S75-5606-06)

Genecon V3 (Narika B10-2634)



Coil set (Narika S75-5606)

3. Experiment 1: with Solenoid coil (100 turnings) only

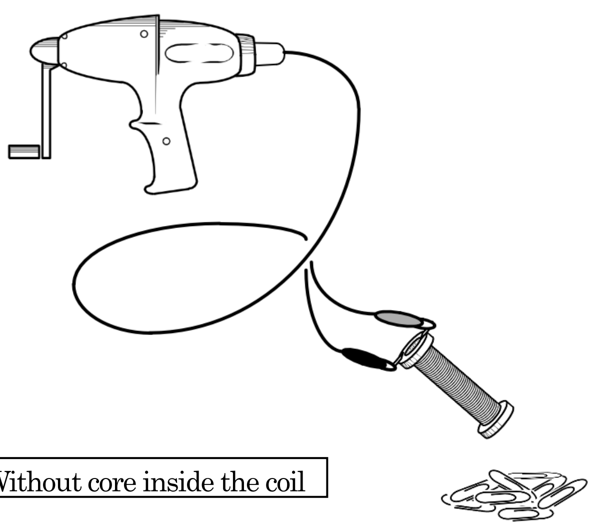
1) Connect Genecon V3 to Solenoid coil (100 turnings).
2) Put paper clips (approx. 20 pcs) on the table.
3) One person will start rotating the handle of Genecon V3.
4) The other person will take the coil and put it close to the paper clips on the table.
5) Write down the amount of paper clips attached to the coil.

4. Experiment 2: Check the difference in the number of solenoid coil turns

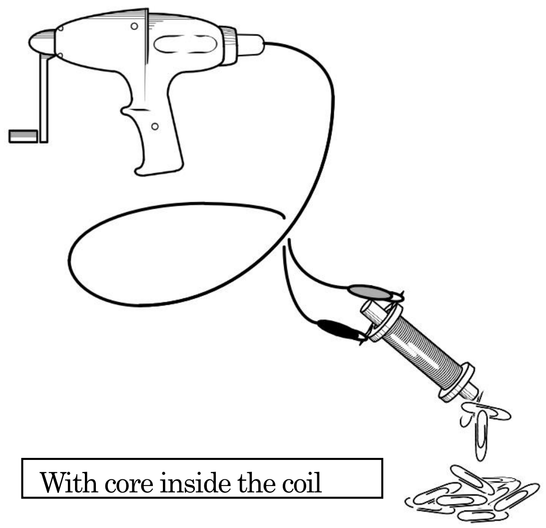
1) Connect Genecon V3 to Solenoid coil (100 turns).
2) Put paper clips (approx. 20 pcs) on table.
3) Insert into Solenoid coil iron core and ensure it will not move by enclosed rubber band.
4) One person will start rotating the handle of Genecon V3.
5) The other person will take the coil and put it close to the paper clips on the table.
6) Write down the amount of paper clips attached to the coil.
7) Change the coil to Solenoid coil (200 turnings) and connect it with Genecon V3.
8) Repeat steps 2-6.

5. Experiment 3 difference in type of cores inserted in Solenoid coil

1) Connect Genecon V3 to Solenoid coil (100 turnings).
2) Put paper clips (approx. 20 pcs) on table.
3) Insert into Solenoid coil enclosed iron core and ensure it will not move by enclosed rubber band.
4) One person will start rotating the handle of Genecon V3.
5) The other person will take the coil and put it close to the paper clips on the table.
6) Write down the amount of paper clips attached to the coil.
7) Exchange iron core for copper core, aluminum core and glass core and repeat steps 2-6.
8) Write down as well how many paper clips were attached to the coil when one person was rotating the handle of Genecon V3 slowly and when rotating the handle of Genecon V3 fast.



Without core inside the coil



With core inside the coil

3. Summary of Experiments

In the table below, fill in the amount of paper clips that were attached to the electromagnet.

[1.] Experiment results: Amount of paper clips attached to the electromagnet

Rotation speed of Genecon V3 handle	Coil turnings	Without core	With core			
			Steel	Copper	Aluminum	Glass
When you turn the handle quickly	100	0 pc	23 pc	0 pc	0 pc	0 pc
	200	0 pc	39 pc	0 ps	0 pcs	0 pc
When you turn the handle slowly	100	0 pc	9 pc	0 pc	0 pc	0 pc
	200	0 pc	10 pc	0 pc	0 pc	0 pc

*This is just example. Actual amount of paper clips might be different.

[2.] From the experiment result table above, which combination is most suitable as an electromagnet?

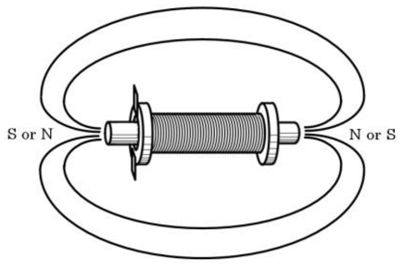
The most suitable is: "coil turnings: 200", with steel core and turning the handle quickly. In case of using core of copper, aluminum, or glass, no clips are attached, which means those materials are not magnetized even with inserted coil. Iron is ferromagnet, which is magnetized in magnetic field. Beside iron, cobalt, nickel and its composition are ferromagnet. Magnetic substances are categorized into: ferromagnet, diamagnet and paramagnet. Copper, aluminum and glass are also Magnetic substances.

[3.] What is the cause of different results if you are turning the handle of Genecon V3 quickly and if you are turning the handle of Genecon V3 slowly?

The different results are caused by the generated electric quantity. If you turn the handle more quickly, generated electric quantity (voltage and current) increases. If you turn the handle more slowly, generated electric quantity (voltage and current) decreases. Therefore, large amount of electric quantity is carried through (solenoid) coil when turning the handle quickly, while relatively small amount of electric quantity is carried through (solenoid) coil when turning the handle slowly. Magnetic force is strengthened when larger amount of electric quantity flows inside electric magnet.

[4.] Based on the results of experiments, in order to create stronger electromagnet, what should we do?

We should: 1) increase the number of solenoid coil turnings, 2) provide larger amount of electricity, and/or 3) use iron core. If we increase the number of solenoid coil turnings, we will have more electric resistance in the coil. In case of connecting DC power supply to electromagnet, if the voltage is constant, amount of current to be carried through will differ depending on the resistance value determined by the number of coil turnings.



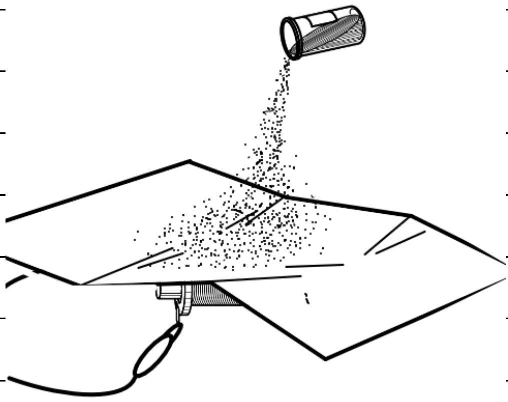
[5.] Draw magnetic field of electromagnet in the drawing below.

We can draw the magnetic field as shown on the right. Note that polarity changes depending on the direction of current. Give your students below questions:

1. How they can identify the magnetic field?

2. How they can determine the polarity?

Note



1. How to identify the magnetic field:

Cover a electromagnet with a white paper and pour iron sand (powder) on the paper. Then, turn the handle of Genecon V3 to observe the magnetic force lines generated by the electromagnet. It may be the good idea to use the "Mag Chip" provided by Narika.
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.

2. How to determine the polarity:

Use a magnetic compass. Around the electromagnet, place some compasses to indicate the polarity when turning the handle of Genecon V3.

Generating Electric Current by Magnetic Field 1

1. Learning Outcome

We can exemplify how magnetic field is generated by electric current through the experiments of Oersted, Ampere's Right-hand grip rule, and electromagnet as we did in the previous Units. In this Unit, we are going to examine, when electric current is carried through a coil, how magnetic field is generated and affect another adjacent coil. Insert an iron bar (core) into two coils that are not connected to each other. Then, connect a hand-held generator "Genecon V3" to one of the coils, and connect a Galvanometer to the other coil. By turning the handle of the Genecon V3 to pass an electric current through a coil, we will check how the Galvanometer connected to the other coil would be affected.

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.

Learning outcome of this Unit is for students to better understand the phenomena of experiment of M. Faraday through their hands-on experience.

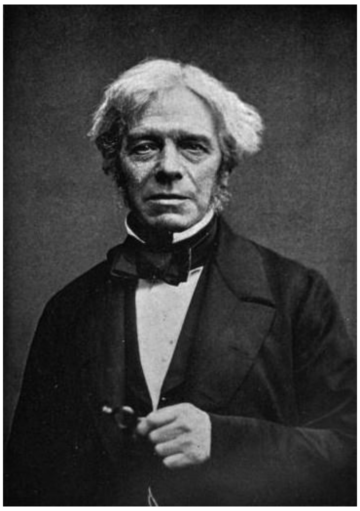
2. Historical Background

Michael Faraday (1791 - 1867) was an English scientist who contributed to the fields of electromagnetism and electrochemistry. His main discoveries include: electromagnetic induction, diamagnetism and electrolysis. It was by his research about magnetic field around a conductor carrying direct current, that Faraday established the basis for the concept of the electromagnetic field in physics.

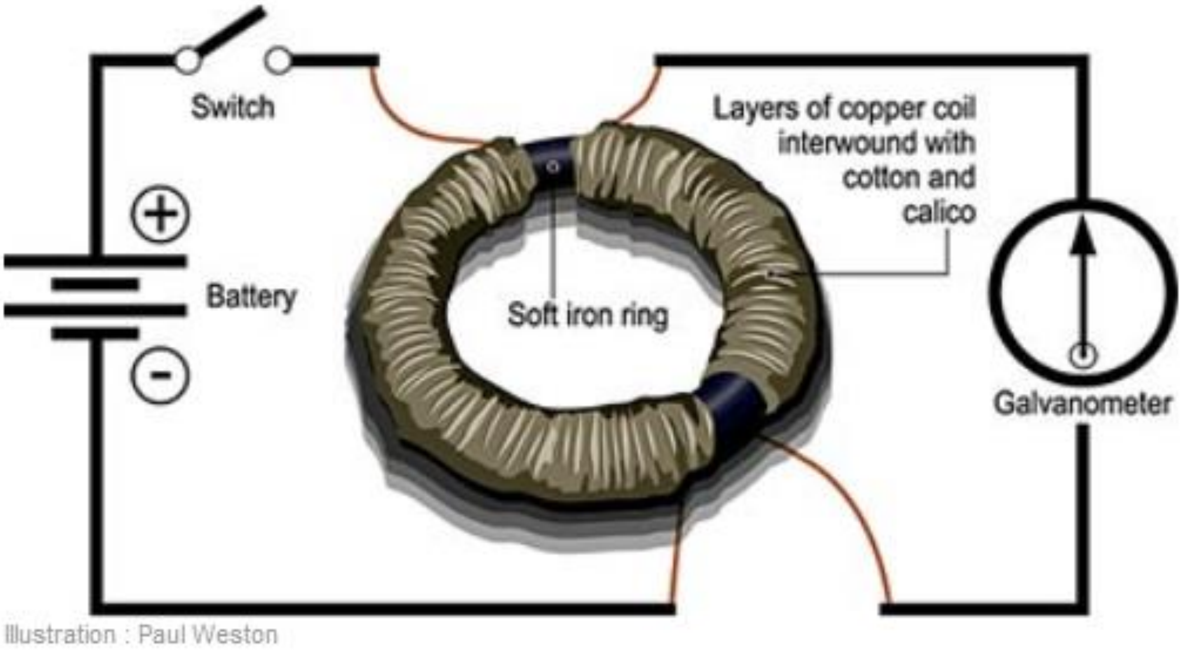
When Oersted discovered that electricity produces magnetism, Faraday wondered if magnetism could produce electricity. In 1831 he showed that it can. In Faraday's first experimental demonstration of electromagnetic induction, he wrapped two wires around opposite sides of an iron ring. He plugged one wire into a galvanometer, and watched it as he connected the other wire to a battery. When the battery was connected, the needle of the galvanometer leaped into action, registering current in one coil. However, the effect quickly faded and the needle soon detected no current, even though the battery was still connected.

Finally years later, he found that if the battery is switched off and on repeatedly, the effect can be iterated over and over again. When the battery is connected, electrons flow along the copper wire of one coil round the windings around the ring. The effect of this is to induce magnetism in the ring. A magnetic field of excited electrons is created, producing an electrical current in the other coil, which is inside the magnetic field. This is one of Farady's great discoveries: **Reciprocal (Mutual) Induction**: production of current in a coil only when changes of current occurs (no change occurs during current carrying).

His major accomplishments:
- Electromagnetic induction
- Faraday effect
- Faraday constant
- Faraday's law of electrolysis
- Electric line of force
- Faraday gauge
- Faraday cup



Michael Faraday
http://en.wikipedia.org/wiki/
File:Fara day-Millikan-Gale-1913.jpg



Nowadays **Reciprocal (Mutual) Induction’s** Definition: It is the phenomenon in which a change of current in one coil causes an induced emf (electromagnetic field) in another coil placed near to the first coil. The coil in which current is changed is called primary coil and the coil in which emf is induced is called secondary coil. Consider two coils placed near each other. When current is passed through the primary coil, magnetic flux is produced. This magnetic flux is also linked with the secondary coil. If the current is changed by varying the resistance in the primary circuit, the magnetic flux also change. As this changing flux is linked with the secondary coil, it induces an emf in it. This phenomenon of inducing emf in a coil by changing current in another coil is known as mutual inductance.

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 transplant body. For teachers, Genecon V3 significantly helps their explanation to students regarding the fact that motor and generator are identical.

[2] Galvanometer GM-6000:

Galvanometer is equipment used to detect current with sensitivity of approx. 2.5 μA and full scale indicating ±50 μA. Being equipped with amplifier (approx. 1000x), this is a special extremely sensitive Galvanometer which can detect very small amount of electric current.

For instance, it is able to detect small amount of electric current generated by the electromagnetic induction that happens when a magnet is brought near a straight wire. Also, it is still able to detect very small amount of electric current generated by the electromagnetic induction that happens when a long wire interacts with the “magnetic field lines of the earth” instead of a magnet.

Galvanometer GM-6000

(Narika A05-7120)

- Voltage sensitivity: approx. 1.6 x 10^{-4} V/mm
- Current sensitivity: approx. 2.5 x 10^{-6} A/mm, Full scale indicating ±50 μA (center zero)
- Amplification degree: Differential amplification, Amplification factor 60dB

4. Inspection of Equipment and Preliminary Experiment

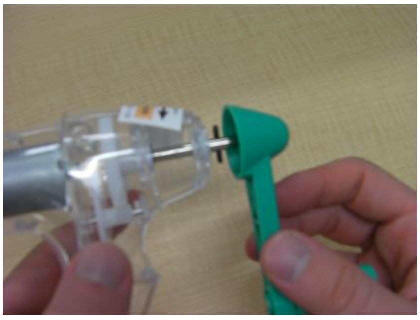
Preliminary experiment is mandatory step by teachers to check the procedure of experiment and detect any defect/failure of the instrument to be used, prior the experiment by students. In this Unit, check Genecon V3 and Ampere Apparatus with the procedure mentioned below.

1) Procedure for Genecon V3 operation check

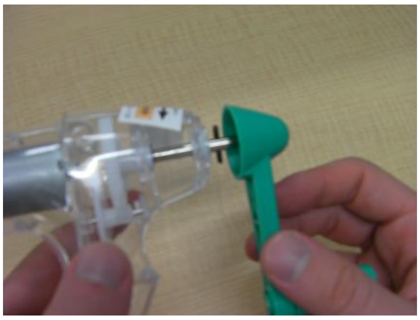
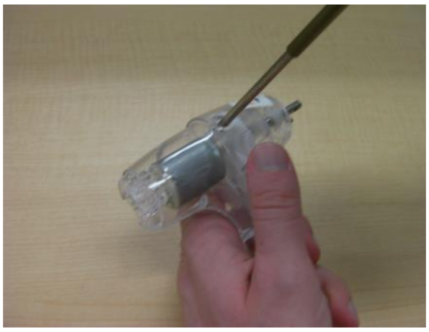
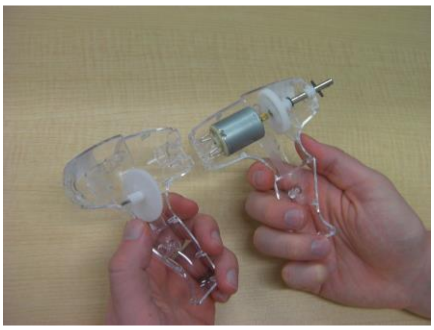
Steps	What to do	Actions
1	Connect the miniature-bulb-adapter with Genecon V3. Or connect Genecon V3 with the "Miniature Bulb Holder with Leads" through the "Lead for Genecon V3 with Alligator-clips". (Note: The photo shown on the right is using miniature-bulb-adapter.)	
2	Turn the handle of a Genecon V3 gently both clockwise and anti-clockwise.	
3	Check if the handle is rotating smoothly.	In case you find the handle is loosely rotating, fix it following the below procedure 2) a). In case you find breakage with gear(s), change the gears following the below procedure 2) b).
4	Check if the bulb of the miniature-bulb-adapter (or, of the holder) is lit.	In case it is not, change the bulb to a new bulb.

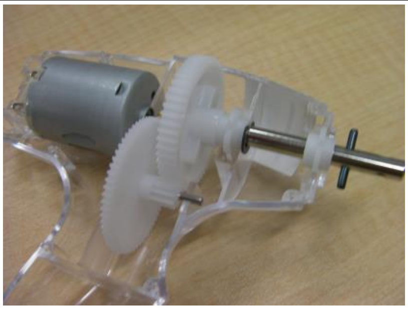
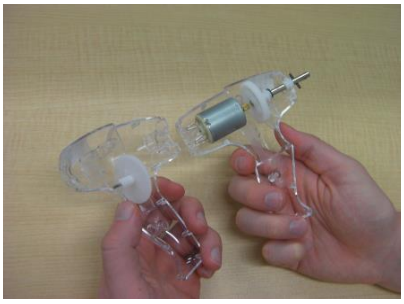
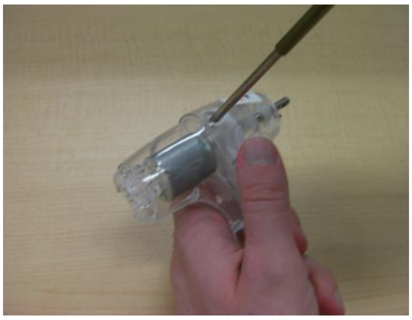
2) Maintenance of Genecon V3

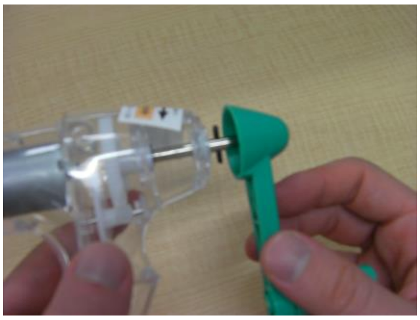
a) How to fix the handle

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	
2	Engage the handle firmly with the shaft.	
3	Return the set screw again to the handle.	
4	Firmly fix the set screw using a hexagon wrench.	

b) How to replace the gear(s)

Steps	What to do	Actions
1	Detach the set screw of the handle using a hexagon wrench.	
2	Take out the handle out of the shaft.	
3	Detach the head capsule with fingers. If needed, use a flat-blade screwdriver.	
4	Take out the two screws used for the body using a phillips-head screwdriver.	
5	Dismantle (split up) the body into two parts.	

Steps	What to do	Actions
6	Take out the installed gears.	
7	Replace the damaged gear(s).	
8	Set all the gears again in the body.	
9	Set the two "guiding spacers" of the shaft-with-gear at the predetermined location.	
10	Assemble the body.	
11	Fix the assembled body with the two screws using a phillips-head screw driver.	
12	Attach the head capsule.	

Steps	What to do	Actions
13	Engage the handle with the shaft.	
14	Fix the handle with set screw using a hexagon wrench.	
15	Operation check by rotating the handle.	

3) Procedure for Galvanometer operation check

Steps	What to do	Actions
1	Remove a protection wire between the two terminals. Then, connect the cables to each of the terminals.	
2	Check if the amplifier power source for the Galvanometer works by setting the toggle switch on the front panel to "1000x".	Pilot lamp next to the toggle switch will turn on. If not, replace the battery because the remaining battery level is depleted.
3	Set the indicating needle of the Galvanometer to "Zero (0)" by using the "zero point" adjusting knob on the front panel.	The indicating needle should be set to "zero" point. 1) If not, protection wire between the two terminals might remain. Remove it. 2) If not, the remaining battery level might be depleted. Replace it to a new one.
4	End of the operation check.	

4) Procedure for replacing battery for Galvanometer

Steps	What to do
1	Remove the cover for battery box at the bottom surface of Galvanometer.
2	Remove the dry cell battery (PP3, 9V) from the battery holder.
3	Set a new dry cell battery (PP3, 9V) in the battery holder and put the battery box cover back.
4	Check if Galvanometer works normally.

5. Teaching Scheme

	Teaching Schemes	What to teach?	What to emphasize? (Precautions)	Class-time-duration
1	Introduction	● Historic Background ● Electric current generates magnetic field. ● Ampere's law ● Experiment by Oersted ● Faraday's electromagnetic induction	● Introduction to Electrodynamics and Electromagnetism. ● Topic on the interaction between Maxwell and Faraday would be more effective.	10 min
2	Experiment	● Make pairs of two students. ● Two coils and an iron bar (core) ● Connecting with Genecon V3 ● Galvanometer	● Connect one coil to the Genecon V3 ● Connect the other coil to the Galvanometer ● Both coils are not connected with each other. ● Let students reverse the direction of turning Genecon V3.	30 min
3	Summary	● Let students fill in the result on the Students' worksheet. ● How to fill in is free.	● Let students record their findings in detail.	10 min
4	Wrap-up and Students' presentation	● Urge students to make presentation on what they filled in on the worksheet.	● Try to cascade what the students learned in this Unit to the next.	10 min

[NOTE:] Referring to above, teachers should adjust what they actually teach according to the level of their schools.

6. Experiment for Students – Excerpted from Students' Worksheet

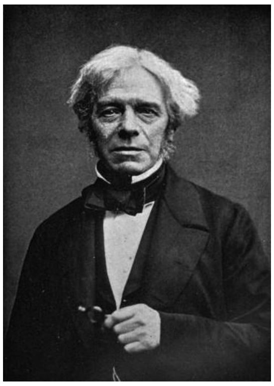
Generating Electric Current by Magnetic Field 1

1. Faraday's Experiment with Electromagnetic Induction ~ Michael Faraday ~

Years after A. M. Ampere discovered the Ampere' law (right-hand rule) in 1820, by which basic theory of electricity and magnetism was proposed, William Sturgeon and Joseph Henry discovered and invented electromagnet in 1828.

Michael Faraday has, derived from the Oersted discovery of fact that electric current makes magnetic field, started to think that magnetic field can make electricity. He had been conducting research related to magnetic field created around electrical conductor when direct electric current was flowing.

Faraday created two coils by wrapping nichrome wires on an iron ring. When he supplied electric current to one of the coils, he found that the current flow instantaneously in the other coil, as well (in 1831).



Michael Faraday
http://en.wikipedia.org/wiki/
File:Faraday-Millikan-Gale-1913.jpg

Faraday's Apparatus (Narika)

2. Experiment with Electromagnetic Induction

1. Purpose of the Experiment:

To confirm Faraday's experiment with electromagnetic induction.
By using two coils and iron core connected with Genecon V3 as an electric power source, verification of the current using a Galvanometer.

2. What to prepare:

*Genecon V3: 1 pc (Narika B10-2634)
*Coils (400 turns) & Steel core: 2 pcs (Narika B10-2631-05)
*Galvanometer GM-6000: 1 pc (Narika A05-7120)
*Cable with clips (red and black): 1 pc (Narika B10-6503)

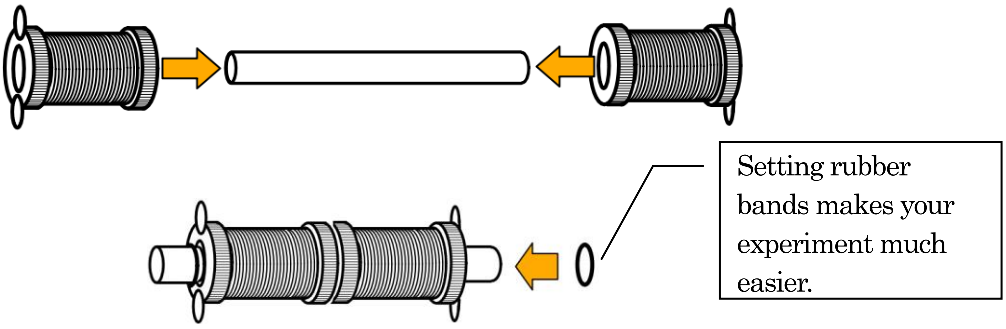
Genecon V3
(Narika B10-2634)

Galvanometer GM-6000
(Narika A05-7120)

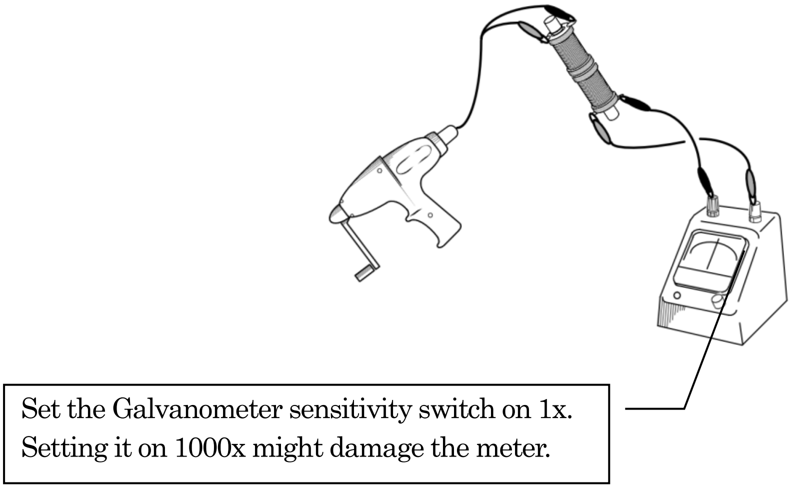
Coils
(Narika B10-2631-05)

3. Procedure of the Experiment:

1) Insert one iron core into two coils in series.
2) In order to prevent the coils would not fall off from the iron core, set two rubber band at either end of the iron core (as shown on the drawing bellow).



3) Set the Galvanometer sensitivity switch on x1 (Do not set it to 1000x).
4) Connect terminals of one coil, through cables with clips, to Galvanometer GM-6000.
5) Connect terminals of the other coil, through a cable with clips, to Genecon V3.
6) Start turning the handle of Genecon V3.
7) Observe the needle deflection of Galvanometer and write it down.



3. Summary of the Experiment

1. How does the needle of Galvanometer deflect when you turn the handle of Genecon V3?

Acceptable answers for this question would be: 1) Maximal deflection of the needle is shown at the beginning of turning the handle, 2) Deflection of the needle becomes smaller during turning handle, and/or 3) Deflection of the needle is synchronized with the timing of turning handle, rather than such a simple answer as "The needle of Galvanometer deflects when turning handle of Genecon V3."

2. How does the needle of Galvanometer deflect when you turn the Genecon V3 handle alternatively clockwise and anti-clockwise?

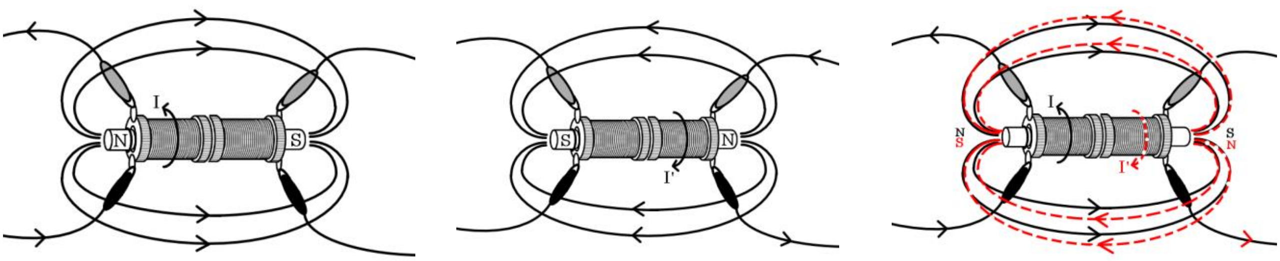
Acceptable answers for this question would be: "Maximal deflection of the needle is shown every time we change the direction of turning the handle." in addition to such an answer as "the direction of the needle deflection changes when we change the direction of turning the handle from clockwise to anti-clockwise and vice versa".

3. Even though the two coils are not connected via conducting wire, when you turn the handle of Genecon V3, the needle of Galvanometer deflects, which means electricity flows through the coils. Think about possible reasons why does electricity flow and write it below.

When electric current flows through Coil 1 by using Genecon V3, North and South poles occur on the iron core inserted orthogonal to the Coil 1 (electromagnet phenomenon). Then another magnet force is newly generated (orthogonal to the Coil 2) on the (edge of) iron core inserted into Coil 2, as if it counteracts the magnetic force generated at Coil 1.

4. When iron core is inserted into two of the isolated coils, if we supply electric current to one coil, then electric current is induced to the other coil. Describe below by drawing this phenomenon with flow of electric current and magnetic field.

The phenomenon of "Reciprocal (Mutual) Induction" is interpreted to occur mainly based on following two phenomena; (a) North and South poles occur on the iron core inserted orthogonal to the Coil 1 when electric current flows through Coil 1 by using Genecon V3, (b) North pole occurs at the South pole mentioned in (a) and the South pole occurs at the North pole mentioned in (b), counteracting each other respectively, which induce the electric current in the Coil 2. Since (a) and (b) occur almost concurrently, the whole phenomena can be figured as shown in (c).
In other words, as seen in each of the cases above 1, 2 and 3, electric current is generated only when change in magnetic force lines occurs. Otherwise, Reciprocal (Mutual) Induction does not happen.
Meanwhile, needle deflection of Galvanometer is observed due to the "deflection of the magnetic force lines" in accordance with the pulsating electricity flow generated by Genecon V3. On the other hand, if dry cell batteries or power supply unit are used instead of Genecon V3, needle deflection of the Galvanometer would not appear.



(a) (b) (c)

Generating Electric Current by Magnetic Field 2

1. Learning Outcome

We can exemplify how magnetic field is generated by electric current through the experiments of Oersted, Ampere's Right-hand grip rule, and electromagnet we did in the previous Unit. In this Unit, we are going to examine "electromagnetic induction", the principle on which electric current is generated by magnetic field.

Amount of electric current and voltage generated in accordance with electromagnetic induction is determined by the power of the magnet and/or the number of turnings of used coil. Normally, experiments with electromagnetic induction are done by using a "General Type" Galvanometer in combination with a coil with many turnings. In this Unit, we will make a follow-up experiment of Faraday's experiment of electromagnetic induction by measuring the change in the electric current in accordance with the magnetic field using alnico magnet in combination with a "coil" of one turn wire.

In this way, students will be able to understand that electromagnetic induction happens even when a single wire (coil) is brought near a magnet. In comparison with experiment using a coil of more than 200 turnings. Objective of this Unit is to pursue students' better understanding of electromagnetic induction through their hands-on experiment.

2. Historical Background

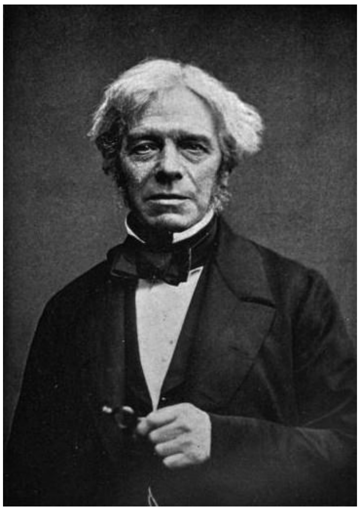
Michael Faraday (1791 - 1867) was an English scientist who contributed to the fields of electromagnetism and electrochemistry. His main discoveries include: electromagnetic induction, diamagnetism and electrolysis. It was by his research about magnetic field around a conductor carrying direct current, that Faraday established the basis for the concept of the electromagnetic field in physics.

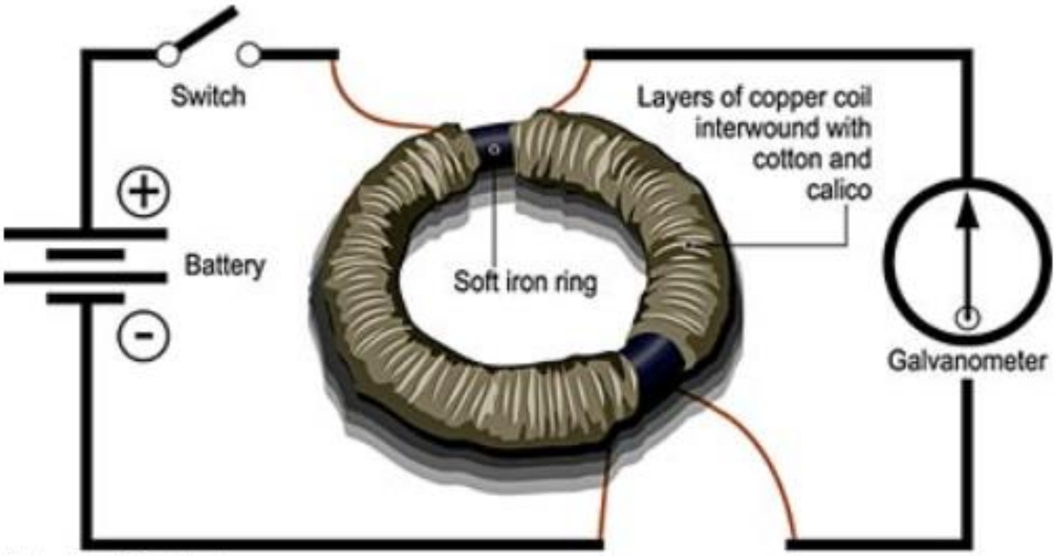
When Oersted discovered that electricity produces magnetism, Faraday wondered if magnetism could produce electricity. In 1831 he showed that it can. In Faraday's first experimental demonstration of electromagnetic induction, he wrapped two wires around opposite sides of an iron ring. He plugged one wire into a galvanometer, and watched it as he connected the other wire to a battery. When the battery was connected, the needle of the galvanometer leaped into action, registering current in one coil. However, the effect quickly faded and the needle soon detected no current, even though the battery was still connected.

Finally years later, he found that if the battery is switched off and on repeatedly, the effect can be iterated over and over again. When the battery is connected, electrons flow along the copper wire of one coil round the windings around the ring. The effect of this is to induce magnetism in the ring. A magnetic field of excited electrons is created, producing an electrical current in the other coil, which is inside the magnetic field. This is one of Farady's great discoveries: **Reciprocal (Mutual) Induction**: production of current in a coil only when changes of current occurs (no change occurs during current carrying).

His major accomplishments:

- Electromagnetic induction
- Faraday effect
- Faraday constant
- Faraday's law of electrolysis
- Electric line of force
- Faraday gauge
- Faraday cup


Michael Faraday
http://en.wikipedia.org/wiki/
File:Fara day-Millikan-Gale-1913.jpg



Nowadays **Reciprocal (Mutual) Induction's** Definition: It is the phenomenon in which a change of current in one coil causes an induced emf (electromagnetic field) in another coil placed near to the first coil. The coil in which current is changed is called primary coil and the coil in which emf is induced is called secondary coil. Consider two coils placed near each other. When current is passed through the primary coil, magnetic flux is produced. This magnetic flux is also linked with the secondary coil. If the current is changed by varying the resistance in the primary circuit, the magnetic flux also change. As this changing flux is linked with the secondary coil, it induces an emf in it. This phenomenon of inducing emf in a coil by changing current in another coil is known as mutual inductance.

Furthermore, he found that current is carried even when magnet is moved inside air core inductor, which lead to the discovery of law of electromagnetic induction, that says "Intensity of induced electromotive force caused in a circuit is proportional to the percentage of change ratio of magnetic field penetrating the circuit." (We will make a follow-up experiment of this law in this Unit.)

3. Introduction of Equipment for Experiments

Galvanometer GM-6000:

Galvanometer is equipment used to detect current with sensitivity of approx. 2.5 μA and full scale indicating ±50 μA. Being equipped with amplifier (approx. 1000x), this is a special extremely sensitive Galvanometer which can detect very small amount of electric current.

For instance, it is able to detect small amount of electric current generated by the electromagnetic induction that happens when a magnet is brought near a straight wire. Also, it is still able to detect very small amount of electric current generated by the electromagnetic induction that happens when a long wire interacts with the "magnetic field lines of the earth" instead of a magnet.

Galvanometer GM-6000
(Narika A05-7120)

- Voltage sensitivity: approx. 1.6 x 10^{-4} V/mm
- Current sensitivity: approx. 2.5 x 10^{-6} A/mm, Full scale indicating ±50 μA (center zero)
- Amplification degree: Differential amplification, Amplification factor 60dB

4. Inspection on Equipment and Preliminary Experiment

Preliminary experiment is mandatory step by teachers to check the procedure of experiment and detect any defect/failure of the instrument to be used, prior the experiment by students. In this Unit, check Genecon V3 and Ampere Apparatus with the procedure mentioned below.

● **Procedure for Galvanometer operation check**

Steps	What to do	Actions
1	Remove a protection wire between the two terminals. Then, connect the cables to each of the terminals.	
2	Check if the amplifier power source for the Galvanometer works by setting the toggle switch on the front panel to "1000x".	Pilot lamp next to the toggle switch will turn on. If not, replace the battery because the remaining battery level is depleted.
3	Set the indicating needle of the Galvanometer to "Zero (0)" by using the "zero point" adjusting knob on the front panel.	The indicating needle should be set to "zero" point. ● If not, protection wire between the two terminals might remain. Remove it. ● If not, the remaining battery level might be depleted. Replace it to a new one.
4	End of the operation check.	

● **Procedure for replacing battery for Galvanometer**

Steps	What to do Actions
1	Remove the cover for battery box at the bottom surface of Galvanometer.
2	Remove the dry cell battery (PP3, 9V) from the battery holder.
3	Set a new dry cell battery (PP3, 9V) in the battery holder and put the battery box cover back.
4	Check if Galvanometer works normally.

5. Teaching Scheme

	Teaching Schemes	What to teach?	What to emphasize? (Precautions)	Class-time-duration
1	Introduction	● Historic Background ● Electric current generates magnetic field. ● Ampere's law ● Experiment by Oersted ● Faraday's electromagnetic induction	● Introduction to Electrodynamics and Electromagnetism. ● Topic on the interaction between Maxwell and Faraday would be more effective.	10 min
2	Experiment	● Make pairs of two students ● Prepare three types of solenoid coils of one turning, three turnings and ten turnings. ● Expose the copper wire by unveiling the tip of enamel wire. ● Connect the unveiled portion of enamel wire with Galvanometer via a cable with clips. ● Change the Galvanometer sensitivity switch to 1000x.	● Unveil both ends of enamel wire to expose the copper wire. ● Just in case you do not have a cable with clips, use the enamel wire to connect with Galvanometer's terminals. ● Make sure you have already changed the Galvanometer sensitivity switch to 1000x.	30 min
3	Summary	● Fill in the result on the Students' worksheet. ● How to fill in is free.	● Let students record their findings in detail.	10 min
4	Wrap-up and Students' presentation	● Urge students to make presentation on what they filled in on the worksheet.	● Try to cascade what the students learned in this Unit to the next.	10 min

[NOTE] Referring to above, teachers should adjust what they actually teach according to the level of their schools.

6. Experiment for students – Excerpted from Students' Worksheet

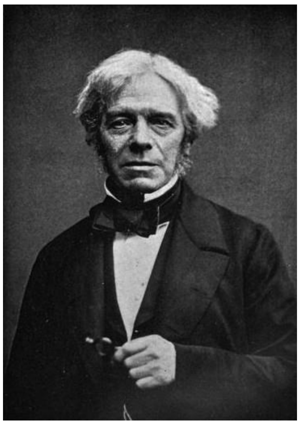
Generating Electric Current by Magnetic Field 2

1. Faraday's Experiment with Electromagnetic Induction ~Michael Faraday~

Years after A. M. Ampere discovered the Ampere' law (right-hand rule) in 1820, by which basic theory of electricity and magnetism was proposed, William Sturgeon and Joseph Henry discovered and invented electromagnet in 1828.

Michael Faraday has, derived from the Oersted discovery of fact that electric current makes magnetic field, started to think that magnetic field can make electricity. He had been conducting research related to magnetic field created around electrical conductor when direct electric current was flowing.
Faraday created two coils by wrapping nichrome wires on an iron ring. When he supplied electric current to one of the coils, he found that the current flow instantaneously in the other coil, as well (in 1831).

Furthermore, he found current is carried even when magnet is moved inside air core inductor, which lead to the discovery of law of electromagnetic induction.



Michael Faraday
http://en.wikipedia.org/wiki/
File:Faraday-Millikan-Gale-1913.jpg

2. Experiment with Electromagnetic Induction

1. Purpose of the Experiment:

To confirm Faraday's experiment with electromagnetic induction by using coils, magnet and Galvanometer.

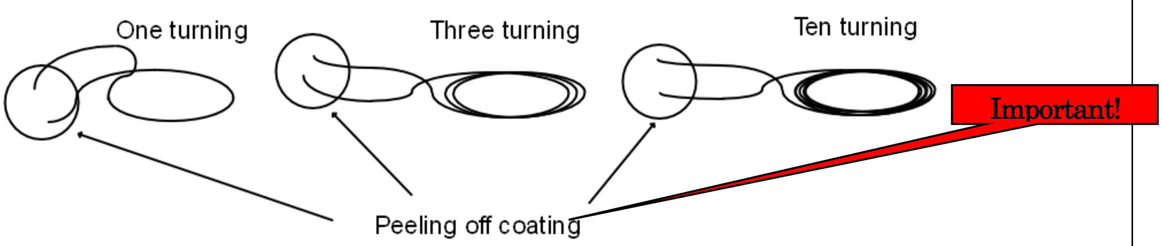
2. What to prepare:

*Galvanometer GM-6000: 1 pc (Narika A05-7120)
*Alnico Bar Magnet: 1 pc (Narika B10-3090-01)
*Enamel Cable: Adequate dose (Narika P70-2251-04)
*Cable with clips (red and black): 1 pc (Narika B10-6503)

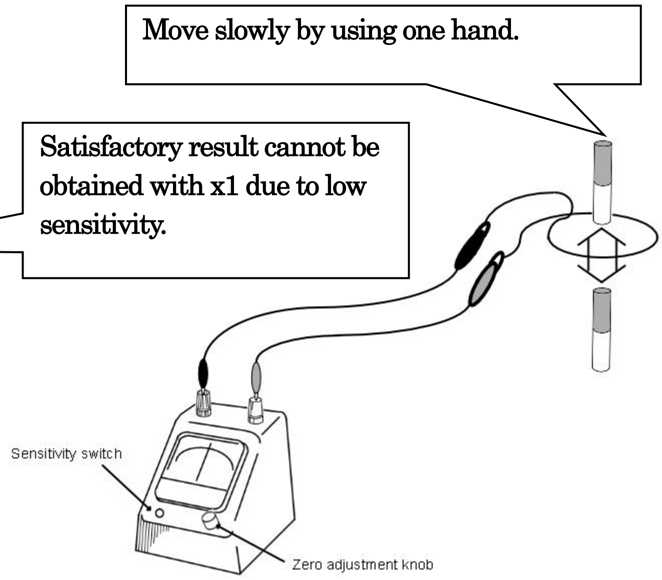
Galvanometer GM-6000
(Narika A05-7120)

3. Experiment 1: ~Electromagnetic Induction caused by taking in/out magnet ~

1) Make 3 coils (solenoids) by using of enamel wire, 1 turning, 3 turnings and 10 turnings.
2) Rub off with sandpaper enamel coating on the pointed ends of each coil until you will see metallic copper.

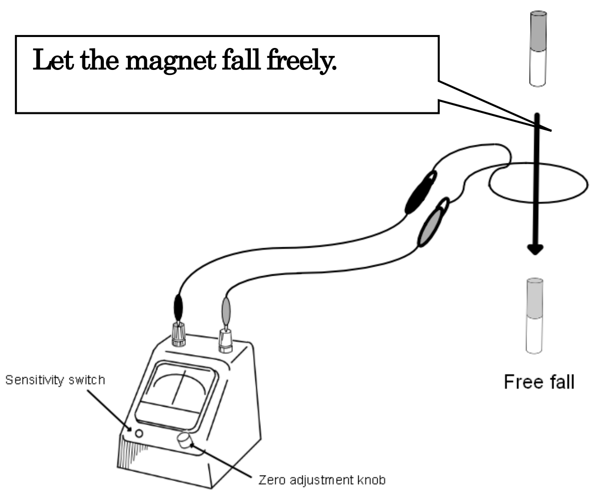


3) Connect two cables with clips to metallic copper part of coil cables by pinching them (as shown on drawing on the right).
4) Connect the other edge of the two cables with clips to terminals on Galvanometer GM-6000 in accordance with the colors on the terminals (red to red and black to black).
5) <u>Change the sensitivity switch on Galvanometer GM-6000 to 1000x position.</u>
6) Hold coil with 1 turning in one hand and insert Alnico bar magnet in and out of the center of the coil.
7) Record in the table below the maximum and instantaneous value shown by the needle on Galvanometer GM-6000 during the course of action.
8) Change the coil with one turning for another and repeat steps 6 and 7 to fill in the blanks of the table below.



4. Experiment 2: Electromagnetic induction by falling magnet

1. Use coils created in experiment 1.
2. Follow the steps 2 to 5 from experiment 1.
3. Hold coil with one turning in one hand and drop through the center of the coil Alnico bar magnet, at the same time swiftly move the hand beneath the coil to catch it.
4. Record in the table below the maximum and instantaneous value shown by the needle on Galvanometer GM-6000 at that time.
5. Change the coil with one turning for another and repeat steps 3 and 4 to fill in the blanks of the table below.



3. Summary of the Experiments

In the table below record the value of the needle on Galvanometer GM-6000 for each case (there is no name of the unit in the value of the needle).

Record table：Results of experiments

Experiment	Value of the needle on Galvanometer GM-6000		
	1 turning coil	3 turnings coil	10 turnings coil
Experiment 1	Three scales (divisions)	5~7 scales (divisions)	10~15 scales (divisions)
Experiment 2	4 scales (divisions)	6~10 scales (divisions)	15~20 scales (divisions)

1. Depending on the number of turnings of coil, how much did the needle of Galvanometer deflected?

Largely (more) deflected = <u>10 turnings</u> ＞ <u>3 turnings</u> ＞ <u>1 turning</u> = Slightly (less) deflected

2. Compare the amplitude of deflected needle of the Galvanometer between Experiment 1 and 2.
   Write down to the underline space > < accordingly.

Experiment 1 __<______ Experiment 2

3. From the results of experiment 1 and 2, explain below the electromagnetic induction.

According to the results of experiment, acceptable explanations would be as follows:

1) According to the result of Experiment 1 and 2, we can tell that the needle deflection of Galvanometer occurs when a magnet is brought near the wire, while the needle deflection of Galvanometer to the other direction occurs when a magnet is brought away from the wire.
2) According to above 1), we can tell the needle deflection of Galvanometer occurs when the pole (S/N) of a magnet is brought near/away from the wire determines the direction of the needle deflection of Galvanometer.
3) According to comparison of the results of Experiment 1 and 2, we can tell that if a magnet goes through wire faster, needle of Galvanometer deflects more (indicating larger divisions), since the needle of Experiment 2 deflected more than that of Experiment 1.
4) According to comparison of the results of Experiment 1 and 2, we can tell that if a magnet goes through wire of more turnings, then needle of Galvanometer deflects more (indicating larger divisions). This means a coil with more wire turnings seems to generate more (larger) needle deflection of Galvanometer.

Note

<u>CAUTION!!!</u>

Height of point where you release the magnet matters when you make the Experiment 2 (A magnet free fall). Hence, if significant difference is not shown, it means the height is too low.

Be sure to place cushion at the magnet landing site as the fallen magnet might be damaged, if it was dropped from sufficiently high point, on the ground or even damage table.

Teacher’s Guide for Selection of Dynamic Electricity Experiments by NARIKA Corporation

Published in Tokyo, Japan by NARIKA Corporation

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Printed in Japan